5.0 CURRENT PROJECT OPERATIONS/TOTAL WATER SUPPLY AVAILABLE

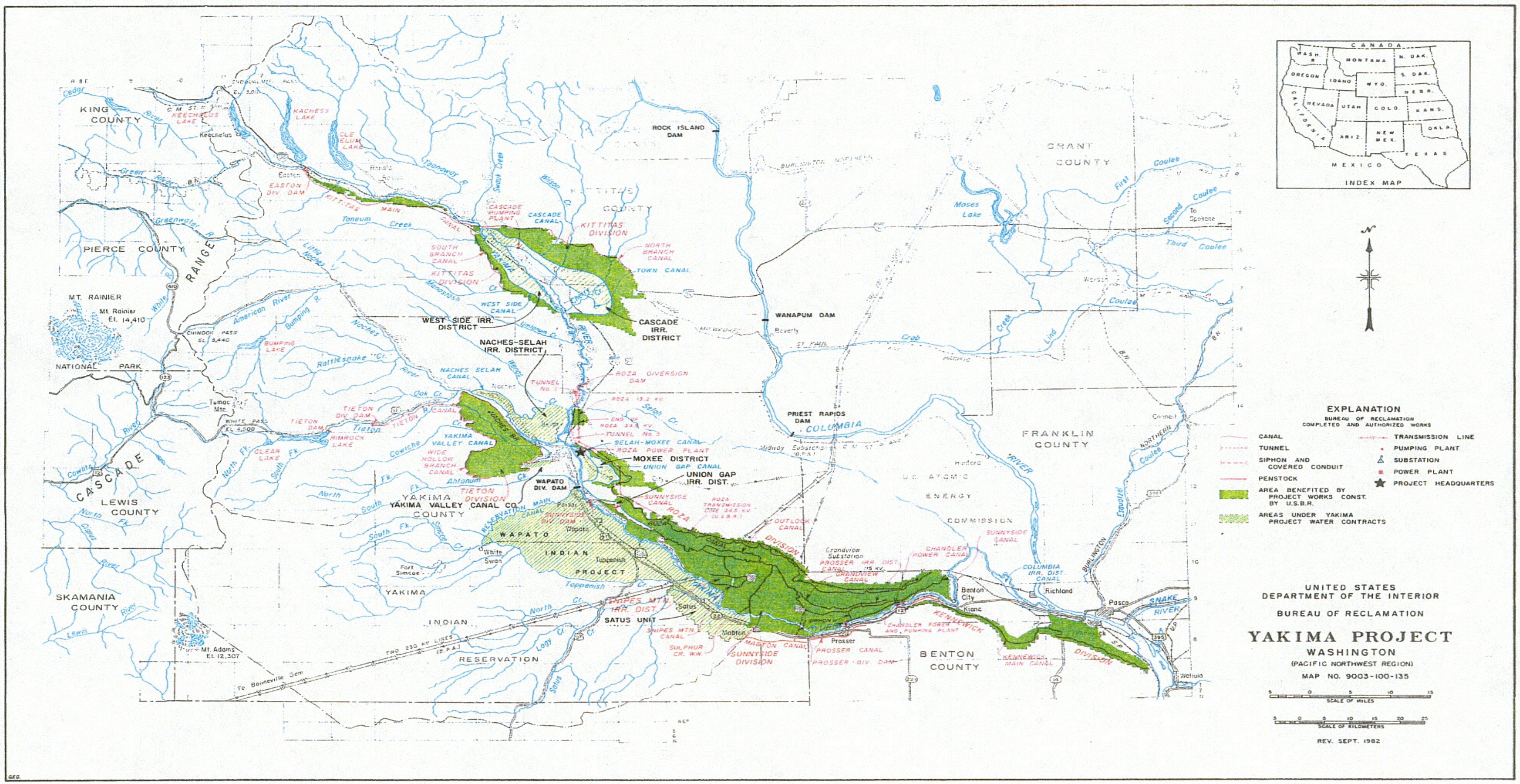
This chapter describes and summarizes the general parameters and functions–physical, contractual, environmental, political and social constraints–which affect the current project wide operation of the Yakima River basin. This is an endeavor to provide insight into the current operations of the Yakima River as managed by the Yakima Project (Project) operations. In any given year, the project, with the current yearly considerations and constraints, develops a plan to manage the Yakima River basin and attempts to provide maximum benefits to each of the water demands in the river system. In this section, a typical operational year with four seasons is described, with the considerations, constraints, and thought processes necessary for defining a year's operations.

The project provides irrigation water for a comparatively narrow strip of fertile land that extends for 175 miles on both sides of the Yakima River in south-central Washington (figure 5-1.). The irrigable lands, eligible for service under the Bureau of Reclamation's (Reclamation) Yakima Project total about 465,000 acres. There are seven divisions in the project. Reservoir storage constitutes one division. In addition, there are six water delivery divisions: Kittitas (59,123 acres), Tieton (27,271 acres), Sunnyside (103,562 acres), Roza (72,511 acres), Kennewick (19,171 acres), and Wapato. The Wapato Division is operated by the Bureau of Indian Affairs (BIA), but receives most of its water supply from the project for irrigation of 136,000 acres of land. Over 45,000 acres not included in the 7 divisions are irrigated under supplemental water supply contracts with Reclamation. Storage reservoirs on the project are Bumping Lake, Clear Creek, Tieton, Cle Elum, Kachess, and Keechelus.

Other project features include 5 diversion dams, 420 miles of canals, 1,697 miles of laterals, 30 pumping plants, 144 miles of drains, 9 power plants (3 in private ownership), plus fish passage and protection facilities constructed throughout the project.

Reclamation computes the entire river basin outflow in calculating total water supply available (TWSA) for all demands, but only physically operates the storage division of the project. The six water delivery divisions and the supplemental contract entities operate their own water delivery/distribution systems.

Reclamation operates the project to meet specific purposes: irrigation water supply, instream flows for fish, and flood control. Irrigation operations and flood control management have been the historic priorities for reservoir operations. Instream flow and requirements of anadromous fish have been incorporated as part of the current routine operation of the system, and take primary status based on legislation or judicial orders at certain times of the water year. Hydroelectric power is produced incidentally to other project purposes. Reservoir storage releases are not made to meet hydroelectric power demand and, at times, power subordination is implemented in order to meet instream flow requirements.


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT
WASHINGTON
(PACIFIC NORTHWEST REGION)
MAP NO. 9003-100-135
REV. SEPT. 1982
EXPLANATION
BUREAU OF RECLAMATION COMPLETED AND AUTHORIZED WORKS
CANAL
TUNNEL
SIPHON AND COVERED CONDUIT
PENSTOCK
AREA BENEFITED BY PROJECT WORKS CONST. BY U.S.B.R.
AREAS UNDER YAKIMA PROJECT WATER CONTRACTS
TRANSMISSION LINE
PUMPING PLANT
SUBSTATION
POWER PLANT
PROJECT HEADQUARTERS
INDEX MAP
KING COUNTY
PIERCE COUNTY
LEWIS COUNTY
SKAMANIA COUNTY
YAKIMA COUNTY
KITTITAS COUNTY
GRANT COUNTY
FRANKLIN COUNTY
BENTON COUNTY
KITTITAS DIVISION
TIETON DIVISION
ROZA DIVISION
SUNNYSIDE DIVISION
KENNEWICK DIVISION
WAPATO INDIAN PROJECT
YAKIMA INDIAN RESERVATION
CASCADE RANGE
COLUMBIA RIVER
SNAKE RIVER

Recreational needs are considered, but are incidental to other project purposes. (It should be noted that the 1992 authorization for and the reconstruction of Clear Creek Dam was primarily based on recreational benefits provided.) The 1994 Title XII legislation provided that an additional purpose of the Yakima Project "shall be for fish, wildlife, and recreation. Also, the existing storage rights of the Yakima Project shall include storage for the purposes of fish, wildlife, and recreation. But, the above specified purposes shall not impair the operation of the Yakima Project to provide water for irrigation purposes nor impact existing contracts."

Reclamation tailors its operations to assure that public safety requirements are satisfied (flood control and recreational use), that water delivery contractual obligations are met (irrigation and power), and that instream flow targets (fish and wildlife habitat) are met. Maximizing flood control, irrigation water delivery, and meeting target streamflows requires continuous water management adjustment.

The five major project reservoirs, (Bumping Lake [1910], Kachess [1912], Keechelus [1917], Rimrock/Tieton Dam [1925], and Cle Elum [1933]), provide most of the physical operations needed to store and release water to meet irrigation demand, flood control needs, and instream flow requirements. Clear Creek Reservoir is operated primarily to maintain maximum elevation for recreational opportunities.

The average annual unregulated flow of the Yakima River basin near Parker (below Union Gap) totals about 3.4 million acre-feet (MAF), ranging from a high of 5.6 MAF (1972) and a low of 1.5 MAF (1977). The average annual irrigation diversion by entities recognized in the 1945 Consent Decree (Decree) totals approximately 2.2 MAF (period of record, 1961-1990). This does not include the other requirements for water in the basin, including instream flow, hydroelectric generation, and municipal and industrial uses. The total demand is supplied through a combination of stored water releases, unregulated flow (natural flow), and return flow. Total storage in the basin is a little over 1 MAF. The remainder of the irrigation demand is supplied through unregulated tributary flow and bypassed reservoir inflow (Note: bypassed reservoir inflow is streamflow into the reservoirs that is released rather than stored) and return flows.

Demand cannot always be met in years of below average runoff. Project operations make use of a monthly forecasting process to provide an advanced indication of water availability. On a daily basis, the project must take into account varying weather conditions, water demand, "travel time" of the flow from the reservoirs to the point of use, inflow from unregulated tributaries, return flow, and other factors to maintain appropriate flow levels at several control points (generally gaging station locations) in the basin.

The Yakima Field Office Manager is responsible for Reclamation's operational control and management of the TWSA for the Yakima River basin. According to "Memorandum Opinion": 'Flushing Flows,' December 22, 1994, Reclamation is: "an entity capable of responding to changing conditions." Each year, in light of the annual prevailing conditions and all current legal considerations, the Yakima Field Office Manager will ensure that the concerned parties are involved as part of the consultation process for operating the basin seasonally. The Yakima Field Office Manager maintains contact with the different groups on a monthly, or as needed, basis via meetings or other forms of communication, to maintain continuity on the development of the year's operation. These include System Operations Advisory Committee's (SOAC) monthly meetings for fishery-related issues, River Operations monthly meetings (future month's plans for operations) for all interested parties, and Managers' meetings (normally, starting in March or earlier if short fall is foreseen, for discussion of the water supply for the ongoing year) for the irrigation district managers and other interested parties. At such meetings, issues of significant concern to project operations in the basin may be addressed with the Yakima Field Office Manager and others, allowing public input for possible inclusion into the seasonal operations stratagem. If consensus cannot be reached, the Yakima Field Office Manager, after review of available science and data, makes the final seasonal decisions.

5.1 OPERATING SEASONS

The thought process for a single season of operations requires a minimum of a 15-month operational year, starting in August of year 1 and ending in October of year 2 (example: August 2000 to October 2001). The operation process started in August will have possible ramifications into the following year's October. All needs or operations for a given season must be evaluated and accounted for in the preceding August, with continual review throughout the season's operation to successfully satisfy the Yakima River system's competing demands. System operations can be divided into four general time segments during the year and these correspond some what closely to the seasons of the year. These segments and their relationships to the irrigation season and water measurement period (water year) are shown in table 5-1. below.

Table 5-1.–Operating Periods and Seasons Yakima River Basin 15-Month Operation Year

Fall			Winter				Spring/Summer				Summer/Fall			
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
							Average Irrigation Season							
		Water Year												

Tables 5-2. through 5-5. which follow, demonstrate the operational considerations and constraints (CCs) during each of the respective seasons. More detailed descriptions of these can be found in the following sections. These charts are intended to show only the time periods within which the CCs are considered when making operational decisions. They do not necessarily show when releases or other changes are actually made.

5.1.1 Fall Operations (August, September, October)

In August, river operators begin the transition to fall operations (August, September, October) which establishes the demands, constraints, and operational criteria for the next season. The fall operations period overlaps summer/fall operations, as the irrigation season is brought to a close. During August, September, and October, when the reservoirs are being drawn down to meet irrigation needs, releases are coordinated to maintain system storage flexibility so that flows can be ensured and provided for spawning, incubation, and rearing of spring chinook eggs and fry operations during the next season of operations. Fishery flow needs are coordinated with SOAC.

During the late August through September 10th period, the mini flip-flop and flip-flop operations are performed, lowering releases from the Upper Yakima Reservoirs and increasing releases from Rimrock to meet irrigation demands in the lower Yakima River system. The flip-flop operation allows Reclamation to protect salmon redds during the incubation and emergence/rearing periods, while minimizing the release demands and maximizing storage. Requests for power subordination are also possible on the lower river system during this period, to maintain instream flows for migration, passage, and rearing.

Table 5-2. demonstrates the CCs during the fall operations period.

Table 5-2. –Fall Operations

Yakima River Basin 15-Month Operation Year																	
Fall Operations (Preparatory)		**Months of Operations**															
Considerations & Constraints		**August**				**September**				**October**				------------------			
1	Average Irrigation Season	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////					
2	Irrigation Supply - Flood Waters																
3	TWSA - Irrigation Supply Period	///////	///////	///////	///////	///////	///////	///////	///////								
4	OWSA - Irrigation Supply Period									///////	///////	///////					
5	Flood Control - Winter																
6	Flood Control - Spring/Summer																
7	Runoff Forecast - Monthly																
8	TWSA Compiled - Monthly																
9	OWSA Compiled - October									/////							
10	TWSA - Short - Prorationing	///////	///////	///////	///////	///////	///////	///////	///////								
11	TWSA - Short - NRP																
12	TWSA - Short - Water Bucket	///////	///////	///////	///////	///////	///////	///////	///////								
13	Storage Control - Historical & Average*	///////	///////	///													
14	YRBWEP XII Flow Period	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
15	Flip-Flop Operation					///////	///										
16	Mini Flip-Flop Operation				//////												
17	Spawning Flows					///////	///////	///////	///////	///////	///////	///////	///////				
18	Incubation Flows											/	///////				
19	Rearing Flows	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
20	Ramping Rates	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
21	Passage Flows	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
22	Flushing/Pulse Flows - Out-migration																
23	Power Subordination	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
24	Hydroelectric Power Operations	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
25	Winter Operations & Ice Watch																
26	Operations - Maintenance - Hydrology	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
27	Operations - Maint. - Dams & Diversion	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
28	Operations - Maint. - Fish Facilities	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
29	Min. Sept. 30 Storage - 76 KAF												//				
30	Maximize Storage Content																
31	Develop Storage Content																

Note: ///////// indicates time period of importance.

5.1.2 Winter Operations (November, December, January, February)

Streamflow into the reservoirs in excess of downstream requirements are stored. Flows are bypassed or releases are made to provide instream flow for the incubation of spring chinook eggs and fry and other fish demands. Release schedules also consider flood control requirements. Flood control operations that may occur are guided by flood control space guidelines for the reservoirs and by forecasts of future runoff. Flood control operations must consider real time streamflow downstream of the dams prior to releasing water. For example, streamflows in the Yakima River at Easton, Cle Elum, Ellensburg, Parker, and Kiona and the Naches River at Cliffdell, and in the Naches River are evaluated prior to any reservoir release. The main objective during flood control operations is to provide maximum protection against flood damage in the Yakima River basin as a whole, without jeopardizing the irrigation water supply for the following year. Other issues or constraints at this time include migration flow and possible power subordination in the lower river system.

Table 5-3. demonstrates the CCs during the winter period.

Table 5-3.– Winter Operations

Yakima River Basin 15-Month Operation Year																	
Winter Operations		**Months of Operations**															
Considerations & Constraints		**November**				**December**				**January**				**February**			
1	Average Irrigation Season																
2	Irrigation Supply - Flood Waters																
3	TWSA - Irrigation Supply Period																
4	OWSA - Irrigation Supply Period																
5	Flood Control - Winter	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
6	Flood Control - Spring/Summer																
7	Runoff Forecast - Monthly									//////				//////			
8	TWSA Compiled - Monthly																
9	OWSA Compiled - October																
10	TWSA - Short - Prorationing																
11	TWSA - Short - NRP																
12	TWSA - Short - Water Bucket																
13	Storage Control - Historical & Average*																
14	YRBWEP XII Flow Period																
15	Flip-Flop Operation																
16	Mini Flip-Flop Operation																
17	Spawning Flows	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
18	Incubation Flows	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
19	Rearing Flows	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
20	Ramping Rates	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
21	Passage Flows	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
22	Flushing/Pulse Flows - Out-migration																
23	Power Subordination	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
24	Hydroelectric Power Operations	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
25	Winter Operations & Ice Watch					//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
26	Operations - Maintenance - Hydrology	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
27	Operations - Maint. - Dams & Diversion	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
28	Operations - Maint. - Fish Facilities	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
29	Min. Sept. 30 Storage - 76 KAF																
30	Maximize Storage Content																
31	Develop Storage Content	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////

Note: ///////// indicates time period of importance.

5.1.3 Spring/Summer Operations (March, April, May, June)

Streamflow into the reservoirs in excess of downstream requirements is stored. Irrigation diversion demand is largely met from natural flow accruing below the reservoirs from unregulated tributaries. Some supplemental releases are made for instream flow maintenance for incubation and rearing where unregulated inflow downstream of the dams is inadequate. Occasionally releases are made for enhanced passage flows, spikes, or other flow enhancement needed to encourage smolt out-migration. Other issues or constraints at this time include migration flows and possible power subordination in the lower river system. Releases to maintain appropriate flood control space are provided as necessary. Spring/summer flood control operations at the five project reservoirs occur each water year, even during most dry years. The volume of runoff potential is estimated by the runoff forecast in balance with the TWSA process. The runoff forecast and the flood space guide curves are taken into account in the refill process and in the timing of attaining a full storage system. Reservoirs are generally brought to their highest level during the late May through June time period. Some of the reservoir inflow is stored and some is passed through the reservoir to supplement unregulated flows and return flows to meet downstream diversion demand. Unregulated flow and return flow are generally adequate to meet irrigation diversions through June. However, storage releases have begun as early as May in dry years and as late as August in wet years. The average date of storage control (period of record, 1926-1999) in the Yakima River basin is June 24th.

Table 5-4. demonstrates the CCs during the spring/summer period.

Table 5-4.–Spring/Summer Operations

Yakima River Basin 15-Month Operation Year																	
Spring/Summer Operations		**Months of Operations**															
Considerations & Constraints		**March**				**April**				**May**				**June**			
1	Average Irrigation Season	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
2	Irrigation Supply - Flood Waters			///////	///////	///////	///////	///////	///////	///////	///////	////					
3	TWSA - Irrigation Supply Period					///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
4	OWSA - Irrigation Supply Period																
5	Flood Control - Winter																
6	Flood Control - Spring/Summer	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
7	Runoff Forecast - Monthly	///////				///////				///////				///////			
8	TWSA Compiled - Monthly	////	////			////	///			///	////			///	///		
9	OWSA Compiled - October																
10	TWSA - Short - Prorationing					///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
11	TWSA - Short - NRP			///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
12	TWSA - Short - Water Bucket					///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
13	Storage Control - Historical & Average*					///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	*//
14	YRBWEP XII Flow Period					///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
15	Flip-Flop Operation																
16	Mini Flip-Flop Operation																
17	Spawning Flows	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
18	Incubation Flows	///////	///////	///////	///////												
19	Rearing Flows	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
20	Ramping Rates	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
21	Passage Flows	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
22	Flushing/Pulse Flows - Out-migration					///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
23	Power Subordination	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
24	Hydroelectric Power Operations	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
25	Winter Operations & Ice Watch	///////	///////	///////	///////												
26	Operations - Maintenance - Hydrology	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
27	Operations - Maint. - Dams & Diversion	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
28	Operations - Maint. - Fish Facilities	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////
29	Min. Sept. 30 Storage - 76 KAF																
30	Maximize Storage Content													///////	///////	///////	///////
31	Develop Storage Content	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				

Note: ///////// indicates time period of importance.

5.1.4 **Summer/Fall Operations** (July, August, September, October)

During July, reservoirs are generally operated to maximize storage and still meet downstream demand. From July through the end of the irrigation season (normally October 20^{th}), releases from stored water are required to meet both irrigation needs and Title XII instream flow targets. The system is on "storage control" when reservoir storage must be released to meet downstream demands, including the Title XII target flows. This results in a decline in total storage. Other issues or constraints at this time include passage flows and power subordination. During the summer/fall operations the system is operated to bring the current irrigation season to conclusion. Starting in August, however, operations also switches to establishing the demands, constraints, and operation criteria for the next season.

Table 5-5. demonstrates the CCs for the summer/fall period.

Table 5-5.–Summer/Fall Operations

Yakima River Basin 15-Month Operation Year																	
Summer/Fall Operations		**Months of Operations**															
Considerations & Constraints		**July**				**August**				**September**				**October**			
1	Average Irrigation Season	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////	
2	Irrigation Supply - Flood Waters																
3	TWSA - Irrigation Supply Period	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
4	OWSA - Irrigation Supply Period													///////	///////	///////	
5	Flood Control - Winter																
6	Flood Control - Spring/Summer																
7	Runoff Forecast - Monthly	///////															
8	TWSA Compiled - Monthly	///	////														
9	OWSA Compiled - October												/	////			
10	TWSA - Short - Prorationing	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
11	TWSA - Short - NRP																
12	TWSA - Short - Water Bucket	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////				
13	Storage Control - Historical & Average*	///////	///////	///////	///////	///////	///////	///									
14	YRBWEP XII Flow Period	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
15	Flip-Flop Operation									///////	///---	-----	-----	-----	-----	----//	
16	Mini Flip-Flop Operation								//////	-----	-----	-----	-----	-----	-----	----//	
17	Spawning Flows									///////	///////	///////	///////	///////	///////	///////	//////
18	Incubation Flows															/	///////
19	Rearing Flows	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
20	Ramping Rates	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
21	Passage Flows	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
22	Flushing/Pulse Flows - Out-migration																
23	Power Subordination	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
24	Hydroelectric Power Operations	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
25	Winter Operations & Ice Watch																
26	Operations - Maintenance - Hydrology	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
27	Operations - Maint. - Dams & Diversion	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
28	Operations - Maint. - Fish Facilities	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	///////	//////
29	Min. Sept. 30 Storage - 76 KAF												//				
30	Maximize Storage Content	///////	///////	///////	///////												
31	Develop Storage Content																

Note: ///////// indicates time period of importance.

5.2 OPERATIONS FUNCTIONS, CONSTRAINTS, CRITERIA, AND OBJECTIVES

This section describes the functions, constraints, criteria, and objectives that are taken into consideration during the basin's 15-month operational year. In tables 5-2. through 5-5., the "CC" (referenced in parentheses) corresponds to the number used in the tables to designate a "consideration or constraint." The main project operations are for irrigation, fisheries (fish and wildlife), flood control, hydropower, and recreation.

Glossary of Terms

Average Irrigation Season (CC1) -

The average length of the irrigation season is from mid-March through October 20th. From mid-March to the end of March, Yakima Valley irrigation systems are "primed" for operation so that actual delivery of water to individual users can begin on April 1. The major districts' main canals and lateral systems extend for hundreds of miles, requiring 1 to 2 weeks to completely "water-up" the canal system.

Irrigation Demand -

The sum of April through September "entitlement diversions" (existing contractual obligations) is about 2.31 MAF. October entitlements total about 0.12 MAF. To date, entitlement in March is not completely quantified, but some irrigation entities have rights which include flood water use. Entitlement diversions represent only the irrigation water entitlements stipulated in the Decree for the main stem Yakima River basin and do not include irrigation diversions on tributaries or adjudicated streams such as Big Creek, Little Creek, Teanaway River, Taneum Creek, Manastash Creek, Wenas Creek, Cowiche Creek, Ahtanum Creek, and others.

Runoff -

Runoff consists of water from three sources: 1) surface flow, 2) interflow, and 3) baseflow, i.e., runoff contributed by groundwater. These components depict the path of runoff. At any one time, runoff consists of a combination of the three. Generally, during wet-weather periods, surface flow and interflow are the primary contributors to runoff. Conversely, during dry-weather periods, baseflow is the major contributor. Surface flow/runoff is the product of effective precipitation, that is, the rain and snow falling on the basin. Runoff refers to all waters flowing on the surface and in through the shallow soil horizon. Runoff is expressed either in terms of volume or flow rate. The typical unit of runoff volume is acre-foot (43,560 cubic feet or 325,900 gallons) that would cover 1 acre to a depth of 1 foot. Flow rate (discharge) is the volume per unit of time passing through a given point. It is usually expressed in cubic feet per second (cfs) or gallons per minute.

Interflow and groundwater flow are two types of subsurface water runoff. Subsurface water comprises all water either in subsurface storage or flowing below the ground surface. Interflow takes place in the unsaturated zone close to the ground surface. Groundwater flow takes place in the saturated zone, which may be either close to the ground surface or deep in underground water bearing formations.

Unregulated Flow -

For the purposes of project operations, unregulated flow (represented in either the volume or the flow rate) at a given point, is that flow which would occur without the influence of reservoir storage or diversion above the given point (i.e., human interference). Note that this is not an absolute value, but is only used as an indicator of the natural flow.

Bypassed Reservoir Inflow -

Inflow into the reservoirs that is bypassed through the reservoirs rather than stored. Bypasses of flow through the reservoirs do not constitute releases of "stored" water.

Storage Control (CC13) -

The system is on storage control when the flow at the Yakima River at Parker (control point) can be controlled to the Title XII target flows only by using supplemental reservoir storage releases. Once unregulated streamflow fails to meet diversion demand and target flows downstream, reservoir storage releases must be made to meet these demands, causing a depletion of reservoir storage. A reservoir release made in order to supply water to a specific district will not necessarily place the system on storage control. Formal declaration of storage control generally signals the peaking of reservoir storage, the start of a daily demand on storage and the end of any available flood/free water to the irrigation entities. The historic average date of storage control is June 24th, with the earliest occurring on April 1st, and the latest on August 17th.

5.2.1 Runoff Forecast (CC7)

Runoff forecasts are made for the five major reservoirs: Keechelus (KEE), Kachess (KAC), Cle Elum (CLE), Bumping (BUM), and Rimrock (RIM); and at three key checkpoints on the Yakima River system. The three river forecast checkpoints are Yakima River at Cle Elum (YUMW), Yakima River near Parker (PARW), and the Naches River near Naches (NACW). Forecasts are compiled by Natural Resource Conservation Service, National Weather Service, and Reclamation. The current Reclamation forecasting process was begun in the mid-1970s, primarily for flood control purposes. Since 1977, it has been used as one of the components in the analysis of TWSA. No known forecasting process is capable of accurately predicting weather or hydrologic conditions for the upcoming water season in advance, and predictions improve as the upcoming season progresses.

While the runoff volume for a given period can be estimated, the timing of how and when the runoff will occur is usually unknown. The resulting runoff is affected by temperature variation, snowpack density, rainfall intensity, and subsequent snowfall. Warm temperatures or precipitation, especially in combination, greatly affects intensity of runoff after snowpack reaches a density of 40+ percent. Other factors that affect the forecasted runoff volume are evaporation, evapotranspiration, and sublimation.

Each year, beginning in January and normally ending in July, Reclamation develops monthly runoff forecasts. Early forecasts (January and February) are primarily used in flood control operations. By March, forecasts become more suitable for TWSA estimation. The forecasts are made for anticipated precipitation levels of 50 percent, 100 percent, and 150 percent of normal.

The data used in the forecast process include (1) antecedent (preceding) runoff (which is based upon the assumption that the past August through September runoff serves as a relative indicator of soil moisture and base flow runoff conditions that will continue into the current forecast); (2) October through March precipitation at Keechelus Lake, Kachess Lake, Stampede Pass, Cle Elum Lake, Ohanapecosh, Bumping Lake, Rimrock Lake, and Tieton Canal Intake Headworks; (3) April 1st snow water content at Bumping Lake (New), Cayuse Pass, Corral Pass, Domerie Flats at Cle Elum Lake, Stampede Pass, Tunnel Avenue at Keechelus Lake, Olallie Meadows, and Fish Lake; and (4) April through June precipitation at the sites mentioned for group (2), above.

The forecasting technique used is a “multiple regression analysis.” The multiple regression examines established correlations between selected variables and historical runoff, creating an equation which, after current condition factors are supplied, can provide a runoff volume forecast. The coefficients used in the forecast equation change slightly as each new year of data is entered into the historical data base used to establish the regressions. The current historical data base extends from 1940 to1999. When the forecast process is updated with current data, it will provide a forecasted quantity of unregulated runoff volume for the October 1st through July 31st period. Subtracting the total unregulated runoff that has passed by the forecast point from October 1st to the date of forecast calculation (current date), provides a residual unregulated runoff volume expected from the current date of forecast calculation, to July 31st.

The following is an example of the forecast of natural runoff at the PARW which is required use for the flood control allocation curves, TWSA development, and establishing the current year’s volume of Yakima River Basin Water Enhancement Project (YRBWEP) target flows.

The PARW forecast is derived using a step-wise multiple regression procedure and has the following equation (coefficients as of water year [WY] 2000):

$$Y_{PARW} = 0.4860\ X_1 + 15.4666\ X_2 + 1.5619\ X_3 + 13.4801\ X_4 - 1119.51$$

Where:

Y_{PARW} = October - July natural runoff at PARW (1,000 acre-feet).

X_1 = Antecedent July - September natural runoff at PARW (1,000 acre-feet).

X_2 = October - March precipitation. Bumping Lake + Cle Elum Lake + Keechelus Lake + Ohanapecosh + Rimrock Lake + Tieton Intake (inches).

X_3 = April 1st snow water content. Bumping Lake (New) + Cayuse Pass + Corral Pass + Domerie Flats at Cle Elum Lake + Tunnel Avenue at Keechelus Lake (inches).

X_4 = April - June precipitation. Same stations as in X_2 (inches).

1119.51 = A yearly constant (changes slightly on an annual basis as each new year of data is entered into the regressions).

Note: the precipitation and snow courses data used in the forecast process is available on the Columbia River Operational Hydrometeorological System (CROHMS) reporting network.

When precipitation and snowpack are average or above-average, the forecast is a useful tool for the management of the flood operations.

5.2.2 Flood Control

Flood control in the Yakima River basin is supported by the project's five major storage reservoirs: Keechelus, Kachess, Cle Elum, Bumping, and Rimrock. These reservoirs affect the runoff from only 578 square miles (15.8 percent) of the 3,660 square miles located above the PARW gaging station. However, the runoff volume above the reservoirs represents only approximately 50 percent of the 3.4 MAF of unregulated yearly runoff as calculated at PARW. The reservoirs began providing flood control to the lower basin immediately following their construction. Flooding has been significantly reduced each year since storage development.

Following the flood of May 1948, which virtually destroyed the city of Vanport, Washington, Congress required water resource agencies to develop plans to avert similar disasters in the future. Between 1948 and 1955, water forecasts were established for the main stem and all tributaries of the Columbia River, and formal flood operations began in the Yakima River basin. The initial written operating guideline for the Yakima Project, which included flood control, was the “Lindgren filling schedule.” This filling schedule was utilized from approximately 1950 until it was superseded by the system rule curve developed in 1974. The Lindgren filling schedule simply denoted the maximum allowable end-of-month storage content for each of the system’s five reservoirs. The schedule did not account for an inflow forecast, and thus directed the same maximum water surface elevation irrespective of hydrologic factors. In 1973, water was released through a portion of the winter to restrict system storage volumes to at or below the Lindgren filling schedule. Due to subsequent below normal runoff volume, the reservoirs failed to fill and rationing was required during the 1973 irrigation season.

After the 1973 irrigation season, Reclamation, recognizing the huge variability in seasonal runoff volumes and timing, developed the currently utilized system rule (guideline) curve for the Yakima Project reservoirs. The use of the “Flood Control Rule Curve (FCRC),” dated February 25, 1974, by D.R. Yribar, is relatively straightforward and is based upon the premise of attempting to maintain flows at the PARW gaging site at no more than 12,000 cfs during the non-irrigation season and 17,200 cfs, including diversions of 5,200 cfs above PARW, during the irrigation season. The generally accepted flood stage (10.0 feet) at PARW coincides with a flow rate of approximately 15,000 cfs. Inputs to the curve allow the required system storage space to be read from the curve. After determining the required system storage space, the space requirement within the individual reservoirs is determined. The required system storage space is divided as follows: Keechelus 13 percent, Kachess 12 percent, Cle Elum 42 percent, Bumping 13 percent, and Rimrock 20 percent.

Flood Control (Winter Operations) (CC5) -

During the winter months, November through February, the flood guide seeks to maintain 300 thousand acre-feet (KAF) of unfilled storage space to provide protection against a winter flood event before the spring forecasts become available. The 300 KAF of system storage space is distributed as follows: Keechelus (39 KAF) 13 percent, Kachess (36 KAF) 12 percent, Cle Elum (126 KAF) 42 percent, Bumping (39 KAF, not obtainable, normally 20 KAF) 13 percent, and Rimrock (60 KAF) 20 percent.

Flood Control (Spring/Summer Operations) (CC6) -

The flood guide requires variable system storage space of from 0 to 850,000 acre-feet to be available, depending upon forecasted runoff, from March 1st through June 30th. The spring/summer storage space distribution is based on the same percentages as described above. Current reservoir flood control and filling operations include an attempt to provide a more normative hydrographic shape in the mid-May through June runoff season. The flood control period from July to June fills the storage reservoirs in late May or early June, rather than June 30th. This requires the earlier storage of more of the March through May inflow to the reservoirs than in the past. With the reservoirs full June 1st, the inflow to the reservoirs must be bypassed downstream, resulting in a more normative shaped hydrograph for the river system during late May, June, and early July. This modification of the flood control operation requires close monitoring depending upon the current year's runoff forecast. Historically, this will hold June's downstream river flows higher, but not necessarily drive them to flood flows.

With the project being subject to heavy fall rains and/or rain-on-snow events during the winter, the FCRC provides space for regulation of these events. The general flood control operation policy is to use the space available in system storage to avoid or reduce flood events in the down river system based upon the historical flood stages. Events are forecasted by the Northwest River Forecast Center in Portland, Oregon and/or the National Weather Service in Pendleton, Oregon which provide warnings to Reclamation and the public of flood events. After the flooding below the reservoirs recedes, when necessary, storage releases are made from the reservoirs in an attempt to return to levels prescribed in the FCRC and to prepare for the next possible event. Care is taken to make releases only when downstream river stages are below flood stage, and to hold river levels below flood stage, if possible. Safety of Dams issues, however, may require releases from reservoirs for protection of dam facilities even at times when downstream flows are at or near flood state (i.e., avoidance of dam failure).

River Forecast Point – Northwest River Forecast Center	Historical Flood Stage
EASW Yakima River at Easton WA	50.3 GH @ 3,200 cfs
YUMW Yakima River at Cle Elum WA	9.0 GH @ 10,000 cfs
ELNW Yakima River at Ellensburg WA	34.0 GH @ 12,000 cfs
CLFW Naches River near Cliffdell WA	31.0 GH @ 5,000 cfs
NACW Naches River near Naches WA	17.0 GH @ 10,000 cfs
PARW Yakima River near Parker WA	10.0 GH @ 15,000 cfs
KIOW Yakima River near Kiona WA	13.6 GH @ 20,000 cfs

The project has used FCRC as a guideline since 1975. Project operations uses the FCRC as a guide, not as a rule of operation. The FCRC can cause problems when trying to fill the reservoirs to maximum storage for TWSA/irrigation use. If followed to the letter of the rule, flood storage space will be maintained to the end of forecast period and the reservoir storage system may not fill. The FCRC has no considerations built into it for meeting the currently developing "normative river system" operations to meet the fishery resource needs. In most years, project operations seeks to maximize storage in early June and hold maximized storage as long as possible. The FCRC, together with monthly Basin Runoff Forecasts, provides tools needed to operate the reservoirs for both TWSA and flood control. Attempts are made to hold the recommended distribution of flood control space for individual reservoirs, and the Upper Yakima Reach and Naches Reach of the river system.

"Surcharge" storage during any flood event is considered temporary and will be released as soon as possible at a rate that will keep downstream river channels full to capacity as long as there is surcharge in the reservoirs. Surcharge space within a reservoir represents the volume above the normal full pool. (Reservoir Surcharge Policy - 20 March 2000, PNR-Reclamation.)

Operation of the individual reservoirs to maximize storage (CC30) for TWSA requires project operations to watch for an imbalance in the runoff forecast. If the forecast-to-space ratio recommended by the rule curve is less than 5:1, reservoir outflows are reduced to maintain a greater than or equal to 5:1 forecast to space ratio. (Note: "forecast-to-space ratio" is the ratio of the remaining forecast with respect to space available in the reservoir system.) When the Parker forecast is less than 1.5 MAF, the forecast-to-space ratio is pushed to 10:1. When the Parker forecast reaches 750,000 acre-feet, project operations chooses a target fill date that allows a uniform fill and approximately 2 weeks at full storage capacity before the drafting of storage begins. This must be done while paying attention to short and long-term weather forecasts and possible flood events. Project operations currently target a June 1st fill date to provide a normative hydrographic shape for reservoir outflows during the mid-May through June runoff season.

Flood Inducing Conditions -

The biggest floods on the Yakima and Naches Rivers have occurred during the winter months from November through February. Major winter floods occur under two different sets of weather patterns: (1) When a strong westerly, slightly anticyclonic flow combines with a high freezing level and subtropical moisture, the Cascades receive tremendous amounts of rainfall. This is precisely the situation that leads to widespread, major flooding in the rivers flowing off the west slopes of the Cascades. The precipitation often does not extend very far east of the Cascades crest, but enough rain falls in the upper parts of the river basins to cause flooding on the Yakima and Naches Rivers. The November 1990 and November 1995 flood events are classic recent examples. (2) The combination of strong southerly or southwesterly flow, high freezing levels, and subtropical moisture can also lead to major floods on the Yakima and Naches Rivers. These events involve the total basin and bring heavy rain both to the Cascades and to the lower areas of the basin, and general low elevation snowmelt plays an important role in these floods. The February 1996 flood is an example. The Yakima and Naches Rivers also occasionally flood in the spring between March and June. Although more frequent than winter floods, historically, spring floods have been less severe. These floods happen when a significant rainfall event occurs during a period of rapid snowmelt. They are most common in May and June, when the mountain snowpack is melting rapidly. (National Weather Service, Pendleton, Oregon, "Hydrologic Service Area Manual" section 4.)

5.2.3 Total Water Supply Available

Reclamation prepares forecasts of the TWSA (CC8) upstream of the Yakima River near Parker beginning in March, then monthly through July. In a water-short season, forecasts may continue through to the end of the irrigation season. These forecasts are the basis for determining the adequacy of the TWSA (taking into account YRBWEP Title XII target flows) to meet irrigation water entitlements stipulated in the Decree and to assist in deciding the amount of proration, if any, that may be necessary.

The TWSA as defined in the Decree, is "That amount of water available in any year from natural flow of the Yakima River, and its tributaries, from storage in the various Government reservoirs on the Yakima watershed and from other sources, to supply the contract obligations of the United States to deliver water and to supply claimed rights to the use of water on the Yakima River and its tributaries, heretofore recognized by the United States."

Reclamation interprets the above to mean ". . . the total water supply available for the Yakima River basin above PARW, for the period April through September," expressed in a mathematical formula, reading as follows:

TWSA is equal to:
April 1st through July 31st forecast of runoff,
+ August 1st through September 30th projected runoff,
+ April 1st reservoir storage contents,
+ Usable return flow upstream of PARW.

The sum of the above four items (TWSA) provides an estimated total water volume available for use in determining the instream flow targets for the given year in accordance with the operating criteria of the YRBWEP legislation. The total demand to be placed against this TWSA for irrigation, regulation, and flows passing Parker averages 2.7 MAF (including Title XII target flows) in a normal year. (See following table 5-6. for Historical TWSA Estimates and YRBWEP Title XII Target Flows.)

Table 5-6.–Historical TWSA Estimates by Month in KAF, Commencing WY 1977 & YRBWEP Title XII Target flows in cfs, Commencing WY 1995.

Month	**Mar's Apr**	**XII**	**Apr**	**XII**	**May**	**XII**	**Jun**	**XII**	**Jul**	**XII**	**Aug**	**Sep**
YEAR	KAF	cfs	KAF	cfs	KAF	cfs	KAF	cfs	KAF	cfs	KAF	KAF
1977	-	-	2037	-	-	-	-	-	-	-	-	-
1978	3088	-	2678	-	2341	-	-	-	1433	-	920	-
1979	2770	-	2657	-	2460	-	1964	-	-	-	-	-
1980	3268	-	3147	-	2705	-	2121	-	-	-	-	-
1981	2690	-	2367	-	2296	-	1979	-	-	-	-	-
1982	3433	-	3256	-	3005	-	-	-	-	-	-	-
1983	3453	-	3392	-	2941	-	2271	-	-	-	-	-
1984	2956	-	2786	-	2501	-	2200	-	-	-	-	-
1985	3106	-	3111	-	2868	-	2395	-	1529	-	899	-
1986	3061	-	2668	-	2284	-	1800	-	1367	-	-	-
1987	2558	-	2559	-	2297	-	1661	-	1301	-	-	-
1988	2377	-	2253	-	2065	-	1710	-	1349	-	-	-
1989	2946	-	3071	-	2666	-	2192	-	-	-	-	-
1990	3446	-	3268	-	2824	-	2417	-	1717	-	-	-
1991	2938	-	2962	-	2742	-	2261	-	1854	-	-	-
1992	2853	-	2422	-	2268	-	1497 [4]	-	1155 [1]	-	788 [1]	324 [1]
1993	2062	-	1974 [5]	-	1842 [2]	-	1405 [1,2]	-	1126 [1,2]	-	774 [1,2]	415 [1,2]
1994	2169 [2]	-	2016 [2]	-	1691 [2]	-	1191 [1,2]	-	934 [1,2]	-	593 [1,2]	283 [1,2]
1995	3284 [2]	600	3044 [2]	500	2666 [2]	500	2088 [2]	400	1572 [2]	400	-	-
1996	3268 [2]	600	2872 [2]	400	2530 [2]	400	2003 [2]	400	1463 [2]	400	-	-
1997	4055 [2]	600	4542 [2]	600	3836 [2]	600	2670 [2]	600	1935 [2]	600	-	-
1998	3193 [2]	500	2982 [2]	500	2548 [2]	400	2017 [1,2]	400	1536 [1,2]	400	-	-
1999	4179 [2]	600	4198 [2]	600	3649 [2]	600	3017 [2]	600	1913 [1,2]	600	-	-
2000	3319 [2]	604	3305 [2]	604	2691 [2]	504 [6]	2175 [2]	404 [3]	1615 [2]	404 [3]	-	-
Average	3064	(500)	2898.625	(500)	2596.3	(400)	2049.2	(400)	1487.4	(300)	794.8	340.67

XII = YRBWEP Title XII Target Flows – April (or current month) through October.

[4] Based upon adopted forecast.

[5] Does not include October's entitlements, runoff, or return flows.

[6] Includes YRBWEP lease and acquisition (L&A) water.

Water Supply Available for Irrigation -

The Water Supply Available for Irrigation (WSAI) (CC3) is the TWSA less September 30th residual storage and flows passing Yakima River near Parker below Sunnyside Dam, including YRBWEP Title XII requirements, for the period April 1st to September 30th. The WSAI is expressed in the following mathematical formula:

WSAI Estimate April 1st - September 30th is equal to:

#	
1.	+ April 1st through July 31st forecast of runoff,
2.	+ August 1st through September 30th projected runoff,
3.	+ April 1st reservoir storage contents,
4.	+ Usable return flow upstream of Parker,
5.	= **TWSA*** (Total Water Supply Available),
6.	+ YRBWEP Title XII New Acquisitions,
7.	= TWSA + New Acquisitions,
8.	- September 30th reservoir storage content,
9.	- Flow passing Sunnyside Dam,**
10.	= **WSAI** (Water Supply Available Irrigation),
11.	- Non-proratable Irrigation Entitlement,
12.	= Remaining WSAI,
13.	/ Proratable Entitlement,***
14.	= % of Proratable Entitlement.

Note: * Determines YRBWEP Title XII Target Flow.
** Quantity includes YRBWEP Title XII Target Flows and New Acquisition.
*** If the ratio "Remaining WSAI" divided by "Proratable Entitlement" is less than 100 percent, prorationing may be necessary.

TWSA values are defined as follows:

#1&2 – Forecast of runoff is estimated for 3 subsequent precipitation levels – 50 percent of normal, normal, and 150 percent of normal for the ensuing months.

#3 – Current end of month reservoir contents are added. This is the amount of water stored in the reservoirs at the end of the prior month.

#4 – Estimated irrigation return flows are added. Irrigation return flows are the amount of water that returns to the river system after diversion and application to the land. Three estimates based on diversions anticipated with the three precipitation levels are made.

#5 – **TWSA*** – Total Water Supply Available. Sum of values #1 through #4, determines YRBWEP Title XII Target Flow.

#6 – New water acquired via YRBWEP Title XII.

#7 – TWSA + new water acquired.
#8 – September 30th reservoir storage content, residual storage is anticipated carryover storage.
#9 – Estimated flow passing Sunnyside Dam (PARW). This estimate includes undiverted unregulated flow, operational spills based on historic flows in similar water years and includes quantified YRBWEP Title XII target flows and new water acquisitions.
#10 – **WSAI** – Water supply available for irrigation entitlements.
#11 – Full quantified non-proratable irrigation entitlements.
#12 – Remaining water supply available for proratable irrigation entitlements.
#13 – Total proratable entitlements.
#14 – Percent of available proratable entitlement.

Return Flow -

Return flow is the water either on the surface or seeping underground toward a stream after water has been spread overland to irrigate crops or been lost to evapotranspiration. The principal components making up return flow are percolation (to the hydraulically connected aquifer) and surface losses from irrigation, seepage losses from "on-farm" and district conveyance systems, and operational losses from these conveyance systems. The timing of the return flow and the location of the flow in the river system determine whether or not the flow can be reused again.

Return flow resulting from irrigation diversions which are usable for diversion above Sunnyside Dam (PARW) are an integral part of the TWSA estimate. The return flow is dependent upon the level of diversion which is conditioned by the amount, time, and availability of runoff. The return flow will vary from year to year, but the usable portion is a fairly uniform base flow which is generated by fairly stable upstream diversion rates. The return flow volume projected to be usable is 400,000 acre-feet in high runoff years, 375,000 acre-feet in average years, and 350,000 acre-feet in low runoff years. (See table 5-7. below)

Table 5-7.–Projected Usable Return Flow (af) for TWSA development, April through September + October

Month	Monthly Projection	Projected Accumulated Remaining Return Flow in Acre-Feet		
---------	---------	Low Runoff Year	Average Runoff Year	High Runoff Year
April	42,000	350,000	375,000	400,000
May	64,000	308,000	333,000	358,000
June	66,000	250,000	269,000	288,000
July	78,000	186,000	203,000	222,000
August	73,000	110,000	125,000	140,000
September	52,000	39,000	52,000	65,000
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October	21,000	16,000	21,000	26,000

(Usable return flow as used in computation of TWSA since 1980 except the extreme water-short years: 1992, 1993, 1994.)

For the daily operation decision process, it is possible to get a rough estimate of daily return flow by adding the diversions of the YTID and the Kittitas Reclamation District (KRD) to the total diversions of the small irrigation users above Sunnyside Dam (PARW) and dividing by 2 to indicate the daily volume. Note that this is only an indicator and not an absolute quantity, as it takes up to 2 months for upstream diversions to translate into the full affect of return flow. Usable quantities of return flow from the system are developed by late April or early May in most years.

1945 Consent Decree -

During years of low runoff, disputes developed over the use of water from the Yakima River. In 1945, the District Court of Eastern Washington issued a decree under Civil Action No. 21, referred to as the 1945 Consent Decree. The Decree is a legal document pertaining to water distribution and water rights in the basin. The Decree established the legal guidelines under which Reclamation should operate the Yakima Project system to meet the water needs of the irrigation districts that predated the Yakima Project, as well as the entitlements of divisions formed in association with the Yakima Project. The Decree determined water delivery entitlements for all major project irrigation systems in the Yakima basin, except for lower reaches of the Yakima River near its confluence with the Columbia River. The Decree states the quantities of water to which all water users are entitled (maximum monthly and annual diversion limits) and defines a method of prioritization for water-deficient years. The water entitlements are divided into two classes—non-proratable and proratable. See descriptions below for Non-proratable Entitlements and Proratable Entitlements.

TWSA Irrigation Entitlements -

For compilation of the TWSA, Reclamation recognizes and limits diversion entitlements, except for minor diversions and adjudicated minor tributary streams, to quantities provided by: a) the Limiting Agreements (1905-1913) signed by over 50 appropriators of natural flows; b) water delivery contracts between the United States and water user entities; c) recognized non-subscribers to 1905 limiting agreements claimants; and d) by provisions of the Decree and subsequent Acquavella rulings. During non-prorated water years, unused TWSA irrigation entitlements are not carried over to the next month's TWSA entitlements for that entity. The water supply not used from these entitlements is rolled into the next TWSA supply forecast for re-allocation to supply the demands of the river basin during the remaining months of the water supply period. See "Entitlement Summary" appendix D.

Non-proratable Entitlements -

Non-proratable entitlements are to be served first from the TWSA. The non-proratable entitlements are confirmed by the Decree, Article 18. Article 19 established that these entitlements are excepted from proration, and the sum of said amounts are to be deducted from the TWSA prior to determining the entitlements that are subject to proration.

Proratable Entitlements -

All irrigation entitlements are established in the Decree. According to Article 18, all water rights are proratable, and of equal priority. However, Article 19 provides for and lists the amounts of entitlements "excepted from proration." Thus, the remaining entitlements become proratable and any shortages that may occur are shared equally by the proratable water users. (See following table 5-8. for TWSA Irrigation Entitlements [af] recognized by the Decree.)

Table 5-8.–TWSA Irrigation Entitlements (af) recognized by 1945 Consent Decree – April 1st through September 30th

Month	Non-proratable	Accumulated Non-proratable	Proratable	Accumulated Proratable	Monthly Total	Accumulated Remaining Entitlement
April	160,973	1,070,271	93,857	1,239,199	254,830	2,309,470
May	186,637	909,298	228,463	1,145,342	415,100	2,054,640
June	182,240	722,661	258,150	916,879	440,390	1,639,540
July	189,640	540,421	268,236	658,729	457,840	1,199,150
August	186,058	350,817	257,822	390,493	443,880	741,310
September	164,759	164,759	132,671	132,671	297,430	297,430

(Irrigation entitlement as used in computation of TWSA since 1980. Note: 1992 entitlement summary shows sightly greater quantity.)

TWSA Irrigation Entitlements (af) recognized by 1945 Consent Decree – October 1st through October 31st

Month	Non-proratable	Accumulated Non-proratable	Proratable	Accumulated Proratable	Monthly Total	Accumulated Remaining Entitlement
October	115,115	115,115	44,025	44,025	159,140	159,140

(Irrigation entitlement as used in computation of TWSA since 1980 Note: 1992 entitlement summary shows sightly greater quantity)

Contractual Irrigation Water Supply

Flood Waters (CC2) -

Flood waters are those waters available in excess of contracted and scheduled amounts or otherwise appropriated waters. They are defined in the Decree as being available for irrigation diversion “when, as determined by the Yakima Project Superintendent, there is flowing over the Sunnyside Dam (passing PARW) flood water in excess of the amount deemed necessary for proper river regulation, including in said amount, the amount necessary to protect fish life, in the river below said dam.” Flood waters are usually available in the early irrigation season and are typically used for priming the irrigation canal systems, frost protection, and some early irrigation demands.

Priming is the initial wetting up of the canal after an extended shutdown period. Water must be introduced into the canal systems slowly. This allows the operators time to verify the water-carrying capability of the canal, to assure that no excessive leakage occurs at turnouts, to fill pipelines, to remove accumulated debris from the trashracks, and generally to prepare the system for delivery to the water-users. It is desirable to have the whole system watered up before delivery to users begin. On a long canal system, (i.e., greater than 50 miles), this takes considerable time.

Currently, as a matter of practice, irrigation districts and canal companies divert and utilize flood waters, during the March, April, and May period. The six major irrigation districts (holders of permits, water rights claims, treaty rights) plus others, make use of this water and are claiming it in the basin adjudication process. It remains to be seen if "flood" water rights will be confirmed in all cases by the court, thereby allowing the irrigation entities to quantify the amount and retain the use of this water.

Limiting Agreements -

Due to early overuse of the available water supply, prior to development of the Yakima Project, no additional irrigation development in the Yakima basin was feasible unless two things were accomplished: first, existing claimants had to agree to restrict their water usage to beneficial use and equitable distribution, especially in the months of July, August, and September; and second, development of a water storage system was necessary to store early season runoff for supplying irrigation demands for new lands.

The limitation on water usage by existing claimants was accomplished by an adjustment of water rights, dealing with more than 50 appropriators on the Yakima and Naches Rivers. The Secretary of the Interior, on December 12, 1905, set forth several conditions that had to be met precedent to further irrigation development in the Yakima basin. One condition, the settlement of existing and vested rights, was accomplished by "Limiting Agreements" wherein the water claimants voluntarily limited their diversions to certain maximum monthly quantities. The basis of this adjustment was a limitation for August and preceding months to the amount actually diverted in August 1905, for September, the limit was two-thirds of this amount; and for October, half of this amount. Of the August diversions, nearly 95 percent of claimed supply (1,900 cfs) was covered by limiting agreements and recognized by the Decree as "non-proratable entitlements" in the TWSA compilation. See "Entitlement Summary" appendix D.

Recognized Non-Subscriber to 1905 Limiting Agreement Claimants -

Several sizable diversions did not subscribe to a limiting agreement. These larger non-subscribers account for over 130 cfs daily mean diversion out of the Yakima and Naches Rivers. The Decree recognized the "non-subscriber to 1905 limiting agreement claimants" and therefore, these are covered as "non-proratable entitlements" in the TWSA compilation. These diversions are unidentified and unquantified in the Decree; however, they are acknowledged as having "heretofore been recognized by the United States." See "Entitlement Summary" appendix D.

Post-1905 Water Rights -

In 1905, the United States obtained a withdrawal of the remaining unappropriated waters of the Yakima River basin for the purpose of developing the Federal Yakima Reclamation Project. After the May 10, 1905 effective date of the withdrawal, Washington State issued a number of new water right certificates under the authority of Chapter 90.03 of the Revised Code of Washington (RCW), enacted in 1917. These post-1905 priority rights were based on water right applications or claims dating from 1906 to 1981, which authorized diversions from the Yakima River and its tributaries. These rights were generally granted for agricultural use. More than 250 of these post-1905 certificates were issued for water diversions from the Yakima River basin above Sunnyside Dam, with priority dates from January 1, 1906 to October 13, 1981. These post-1905 certificates authorized a cumulative maximum diversion rate total of 250 cfs (potentially equivalent to 3.5% of the average daily diversion for irrigation use in the TWSA) that is unaccounted for in the compilation of the TWSA and is not provided for in the Decree. Supplying these diversions during a water-short year impacts the proratable TWSA water users. The Adjudication Court has reviewed many of these post-1905 priority water rights and has apparently found that some of these water uses were not fully developed or have been abandoned or relinquished. The Adjudication Court has confirmed rights to some of these post-1905 certificates in a substantially reduced amount and volume of water. But, even if they represent only a 50 cfs per day diversion from the Yakima basin, the TWSA is impacted in drought years by over 18,000 acre-feet for the period from April 1st to September 30th. During the June 28, 2001 Adjudication Court hearing, Judge Stauffacher reaffirmed the basic principle of Washington Water Law, as declared in 1917 by the Washington State Legislature in RCW 90.03.010, that “as between appropriations, the first in time shall be the first in right.” May 10, 1905, and earlier priority water rights take precedence and have the first right of priority over junior 1905 and subsequent priority water rights. Final determination of the total volume of water being diverted by these post-1905 water right permits, certificates, or claims awaits the completion of the Yakima Adjudication and a Final Decree from the Adjudication Court. In the future, these post-1905 water rights need to be quantified and taken into account as Reclamation develops its yearly TWSA calculation.

Storage Contracts and Stored Water -

Some major entities, such as the Roza Irrigation District (RID) and the KRD, have no natural flow rights and thus their entire water supply is contracted. Other entities needing a supplemental supply are furnished contract water under terms of the Warren Act of February 21, 1911, which authorized Reclamation to contract for the sale of supplemental water from available supplies. These contracts specify the annual and monthly entitlements (non-proratable and proratable). Construction, and operation and maintenance costs of the storage facilities are paid by the entity in proportion to their entitlement. Currently, Reclamation services storage contracts totaling 1.74 MAF, using storage of 1.06 MAF and 1.71 MAF of unregulated runoff to the storage system. Obviously, stored water must be provided as a part of TWSA without reservoir storage being assigned to any specific entity. Entities do not have carryover storage rights as all carryover from one year to the next is considered to be a part of the TWSA for the subsequent year.

Prorationing (CC10) -

When the TWSA is not adequate to meet all irrigation entitlements, prorationing is necessary. Historically, (except WY 1993) the prorationing period has not started until the date of storage control. The amount of proration is determined monthly, biweekly, or as needed, by project operations and this information is provided to water using entities at manager meetings. The non-proratable users can divert their full irrigation entitlements. This amount is deducted from the WSAI with the remainder available for the proratable irrigation entitlements. The recognized quantities of non-proratable and proratable irrigation entitlements are summarized in table 5-8. above. Prorationing has been imposed in 8 of the last 30 years (1970-1999). As examples, proratable water users received 58 percent of their proratable entitlement in 1992, 67 percent in 1993, and 37 percent in 1994. (See table 5-9. for proration levels.)

Table 5-9. - Yakima River Basin – Proration Levels in Recent Years (Starting Water Year 1970)

Percentage of Entitlement

Year	(1) Start of	(2) Storage	(3) S.C. Jul	Apr.	May	Jun	Jul	Aug	Sept	(4) End of Proration Period		
1970	N/A	1- Jul	182							N/A		
1971	N/A	16-Aug	228							N/A		
1972	N/A	17-Aug	230							N/A		
1973	6/10?	1-May	121			80%	80%	80%	80%	end of sea		
1974	N/A	1-Aug	213							N/A		
1975	N/A	20-Jul	201							N/A		
1976	N/A	20-Jul	202							N/A		
1977	1-Apr	1-Apr	91	6-26%	13-50%	50%	70%	70%	70%	end of sea		
1978	N/A	1-Jul	182							N/A		
1979	7/1?	20-Apr	111			75%	75-46%	46%	100%	end of sea		
1980	N/A	1-Jul	183							N/A		
1981	N/A	15-Apr	105							N/A		
1982	N/A	10-Jul	191							N/A		
1983	N/A	20-Jun	171							N/A		
1984	N/A	10-Jul	192							N/A		
1985	N/A	10-Jun	171							N/A		
1986	under ave	26-Apr	116	Hold	under	average	use	for	season	end of sea		
1987	1-Jun	20-May	140			73%	70%	68%	68%	16-Oct		
1988	1-Jul	24-Jun	176				82%	90%	90%	end of sea		
1989	N/A	18-Jun	169							N/A		
1990	N/A	4-Jul	185							N/A		
1991	N/A	8-Jul	189							N/A		

Year	(1) Start of	(2) Storage	(3) S.C. Jul	Apr.	May	Jun	Jul	Aug	Sept	(4) End of Proration Period		
1992	17-May	17-May	138		58%	58%	58%	58%	58%	end of sea		
1993	1-Jun	13-Jun	168	NRP* 85.8	NRP* 72.8	56%	64%	67%	71-67%	30-Sep		
1994	1-May	1-Jun	152	NRP*	47-35%	34%	39%	39%	37%	30-Sep		
1995	N/A	1-Jul	182							N/A		
1996	N/A	26-Jun	178							N/A		
1997	N/A	21-Jul	203							N/A		
1998	N/A	26-Jun	178							N/A		
1999	N/A	29-Jul	210							N/A		
2000	N/A	1-Jul	183							N/A		
2001	1-May	1-Jun	152	NRP*	29%	30%	34%	37%	37%	30-Sep		
2002												
2003												
2004												
2005												

NRP* = Natural Runoff Proportion
(1) = Start of Proration Period
(2) = Storage Control Date
(3) = Julian Date for Storage Control
(4) = End of Proration Period

Natural Runoff Proportion (CC11) -

Natural runoff proportion (NRP) attempts to maximize the use of natural runoff (the unregulated runoff below storage reservoirs) and return flow, and at the same time minimize storage releases to meet demands. The major water users above Parker voluntarily agree to share natural runoff and return flow supply proportionally based upon their entitlements. If reservoir releases are called for prior to storage control and formal prorationing, they will be deducted from the requesting entity's water bucket when prorationing formally begins.

Short Water Year Operations Policy

Based upon experience gained in previous water-short years, operations uses the following framework when faced with below average years. The basic concepts of this policy are: 1) share flood water and return flow during the main runoff period; 2) discourage storage releases during the tail end of the main runoff period (when runoff is unable to meet full demand); 3) allow waters users to shape, via requests in advance, their estimated water supply use pattern ("bucket") during the period of heavy reservoir release (after the main runoff period); and 4) maintain control during end of season (October) operations.

Constraints for Short Water Year Operations -

- April's TWSA is the sum of runoff, storage, and return flows less residual storage and flow passing Sunnyside Dam, including YRBWEP target flows, for the period April 1st to September 30th.

- The WSAI demands provided for by TWSA include only the irrigation non-proratable and proratable entitlements for the period April 1st to September 30th, as stipulated in the Decree.

- The first estimate of TWSA is provided in early March for the period April through September 30th, and thereafter monthly, biweekly, or weekly as needed.

- The water users' share of natural runoff and return flows is evaluated weekly, with minor flow fluctuations supplied out of storage to allow for consistent irrigation operations.

- Prorationing will begin on the date of storage control or earlier, as determined by the Field Office Manager. Formal prorationing will be announced by Reclamation at that time, and updated thereafter monthly, biweekly, or weekly as needed.

- Each entity's water bucket is the sum of its non-proratable entitlement and its share of proratable entitlement for the period, starting with the storage control date (or date set by the Field Office Manager) and ending September 30th.

- If requested by irrigation entities, October water demands, up to maximum entitlement, are met by the October water supply available forecast.

October Water Supply Available – Water-Short Year (CC9) -

If requested by irrigation entities during a water-short year, project operations will develop an October water supply available (OWSA) to meet October water demands (CC4) and, like in TWSA, the entitlements could be subject to prorationing. The OWSA includes natural runoff, return flow, and storage. To meet non-proratable average use for October, project storage must be operated to provide a minimum of 76,000 acre-feet storage as of the end of September (CC29). YRBWEP flows past PARW and estimated carryover storage for the end of the irrigation season are then subtracted from the OWSA. The remainder is the OWSA for requested irrigation entitlements.

Water Bucket (CC12) -

Each entity's water bucket is calculated by summing the non-proratable entitlement and the share of proratable entitlement for the period of declared prorationing, normally starting with the storage control date (or date set by the Field Office Manager) and ending September 30th. Blocking of water ("water bucket") is an excellent water management tool which provides flexibility for an individual entity's needs in water-short years.

Water Transfers During Short Water Years -

During the water-short years of 1994 and 2001, emergency water right transfers were authorized for the declared drought condition irrigation seasons. These emergency water right transfers were intended to alleviate hardships, reduce burdens on water users (irrigation), and increase efficient and maximum use of the water supply during drought conditions.

In 1994, in anticipation of water shortages for irrigation within the Yakima basin, an Emergency Inter-District Water Transfer Program was proposed by Reclamation and criteria for the transfers was developed. These transfers were voluntary, between willing lessees and lessors and only for temporary water supply during the 1994 water year. The transfers were consistent with appropriate State and Federal law, and had the concurrence of the irrigation districts in which they occurred. The rights of other water users (third parties) were not to be impaired. Such transfers were limited to lands that had legal water rights and were being irrigated in full compliance (no "Paper Water") with applicable laws, regulations, and contracts (including the Reclamation Reform Act). These legal responsibilities were not to be diminished by the transfers. Transfers had to be within the capability of Reclamation to deliver, and were considered on a first-come, first-served basis. Transfers were subject to Reclamation's responsibility to protect and maintain resources (these resources include water, fisheries, wildlife, and cultural) held in trust by the United States for the Yakama Nation (YN).

A Water Transfer Advisory Committee (Committee) was established to review transfer requests as they were received and to make recommendations on these requests to Reclamation. The Committee was composed of irrigation district managers from the transferring and receiving districts, an official from the Yakima River Basin Association of Irrigation Districts, a representative of Washington State Department of Fish and Wildlife (WDFW), U.S. Fish and Wildlife Service (FWS), and the YN. The Committee functioned in an advisory capacity with final approval the responsibility of Reclamation. The last emergency water transfers totaled only 3,739 acre-feet, all involving transfers to the RID.

In order to facilitate processing of transfer applications more effectively during the 2001 water-short year, a water transfer process was developed involving a subcommittee of the YRBWEP Conservation Advisory Group (CAG), Washington Department of Ecology (WDOE), and Reclamation. Consultation also occurred with the fish and wildlife agencies (State, Federal, Tribal), and included a review and approval by the Adjudication Court. This expedited approval process was in place effective April 2001, and water transfers were being made May 1, starting date of prorationing. Water transfers totaled 23,039.07 acre-feet indicating that this procedure was effective in expediting the processing of transfers. Most participants appeared satisfied with the 2001 process.

The YRBWEP CAG will continue to work on improvements to the water transfer process. Using the 2001 process as baseline, they will attempt to develop a basin process that provides for voluntary water transfers on a permanent, temporary, or emergency basis. Any new water transfer process will need review and approval by the Adjudication Court.

5.2.4 YRBWEP Title XII Flows (CC14)

One of the purposes of the YRBWEP is to implement water conservation measures to reduce out-of-stream irrigation water diversions from the Yakima River and its tributaries. Savings achieved through improvements to water delivery systems, and changes in operation and management would result in more water remaining in the stream to improve streamflows for fish and wildlife, and to improve the reliability of the irrigation water supply. (See section 4.7.1.)

YRBWEP established new target flows for instream purposes to be maintained past the Sunnyside and Prosser Diversion Dams using criteria based on TWSA. The streamflow targets range from 300 cfs to 600 cfs, depending on the estimate of TWSA. The target flows to be passed at Sunnyside and Prosser Diversion Dams are not instantaneous flows to be uniformly maintained at all times, but are subject to reasonable fluctuations due to project operations. However, for any period exceeding 24 hours, flows at the Sunnyside Diversion Dam (gaging station PARW) cannot decrease to less than 65 percent of the target flow; and the flows at Prosser Diversion Dam (gaging station YRPW) cannot decrease by more than 50 cfs from the target flow. (See table 5-10.)

Table 5-10.–**Title XII target flows based on TWSA**

TWSA (million acre-feet)				Parker and Prosser flows (ft^3/s)	Title XII Minimum flow passed PARW July - September demand in (Acre-Feet)
Apr-Sept	May-Sept	Jun-Sept	Jul-Sept		
3.2	2.9	2.4	1.9	600	117,000.
2.9	2.65	2.2	1.7	500	100,000.
2.65	2.4	2.0	1.5	400	84,000.
Less than above TWSA				300	68,000.

YRBWEP also provides that, as conservation measures are implemented under the conservation program and irrigation water demands are thereby reduced, the target flows will be increased by 50 cfs for each 27,000 acre-feet of diversion reduction above during non-prorated water years. Such increases, however, may not diminish the amount of water that otherwise would have been diverted in years of water proration. In years when the water supply is prorated, the target flows obtained through the implementation of water conservation will be increased above 300 cfs only in those cases where the irrigation return flows previously entered the Yakima River downstream of Parker. Although diversion reductions will be accounted for, a "block of water" will not be set aside under TWSA for maintaining target flows at Parker. Title XII target flows (supplemented by conserved water) will continue to be met from TWSA in the same manner that irrigation demands are met under the Decree. Water entitlements stipulated in the Decree are not changed by Title XII.

Under Title XII, 100 percent of the protectable water acquired by purchase or lease (acquisition), including during years of prorationing, may be used to provide enhanced streamflows for short-term needs such as "flushing flows" to speed the migration of smolts from the Yakima River basin, and to meet longer term needs such as increasing instream flows above the levels currently stipulated by the project operational criteria. Instream uses of this water will be determined by Reclamation in consultation with the SOAC, and provided for in the current operation plan.

5.2.5 Project Operations for Fisheries

Project operations makes efforts to reduce impacts on the fisheries resource and to provide for appropriate water flows, while at the same time providing water for irrigation purposes for users within the project area. Operations takes into account, on a yearly, monthly, and daily basis, the requirements for spawning, incubation, rearing, passage, flushing/spike flows, ramping rates, power subordination issues, and carryover storage in the Yakima basin. The following discussion provides pertinent information on the decision process, support, criteria, and functions that are considered in designing the project operations for fisheries resource protection.

Quackenbush Decision

In September 1980, returning spring chinook salmon migrated up the Yakima River and spawned in portions of the upper main stem. Fish biologists located and identified spawning redds in the reach of the Yakima River lying between the Cle Elum and the Teanaway Rivers. In an October 1980 hearing, the Quackenbush Court directed the watermaster (or current Field Office Manager) to maintain a flow of water in that reach to protect and safeguard the spawning redds. The Court also directed that further hearing on the matter be held commencing in November 1980.

The Court, in November 1980, subsequently ordered and decreed (and the watermaster was instructed) as follows: 1) that a sufficient flow of water be maintained in the above named reach to protect and safeguard the spring chinook salmon spawning area; 2) that the watermaster regulate the flows in such amounts as the watermaster in his discretion may find consistent with protection of the spawning area, after consultation with fish biologists (SOAC); 3) that the watermaster continue to consult with SOAC to provide for the continuing monitoring of the redds and flows in the Yakima River; and 4) that the watermaster, in exercise of his informed discretion to provide for reduction in flows of the river along with the interested parties to this matter, shall study and report to the court on means by which the needs of the project water users can be met through more efficient or less extensive use of project waters, or by modification of project operations or facilities so as to have less impact on the "fisheries resource." The Court also acknowledged the potential for management of the various project reservoirs and releases of water to provide for appropriate water flows during the spawning and rearing periods while at the same time providing water for irrigation purposes for users within the project area.

Project operations continues to use the Court's Order, commonly known as the Quackenbush Decision, to provide legal justification for the management or modification of project operations or facilities to lessen impacts on the fisheries resource and to provide for water flows for fish protection. (For background on this decision, see Quackenbush Decision, section 4.5.2.)

Treaty Rights - Partial Summary Judgement and Other Rulings

Other court rulings or decisions support current operations to reduce impacts on fisheries resource. The YN's Treaty-reserved right for fish equals an amount of water necessary to maintain anadromous fish life in the river (1990). Another motion (1985) requires the Adjudication Court to coordinate management of this Treaty right with the long-standing claimed diversions of water in the basin. The Adjudication Court has ruled that it has interim jurisdictional authority over all Yakima River basin surface water rights claimants and will retain its jurisdiction over all such water rights claimants until the final order is entered and the adjudication is completed. In July 1996, Judge Stauffacher did not quantify the volume of water, but "Ordered, Adjudged, and Decreed" that this diminished Treaty-reserved water right for fish, with a priority date of time immemorial, takes precedence over all other rights in the Yakima basin. (See Partial Summary Judgment, section 4.5.3.1 and Other Rulings, section 4.5.3.2.)

Yakima River System Operations Advisory Committee

SOAC developed out of the 1980 Quackenbush Decision concerning the protection of anadromous fish in the Yakima River. In the November 28, 1980, Supplemental Instructions to the Watermaster, the Court ordered the watermaster to consult with "fish biologists of the Fish and Wildlife Service and the Yakima Tribe" concerning instream flows and the operation of the Yakima Project facilities. In the watermaster's response of May 22, 1981, to the Court , the watermaster recommended that a "working team of biologists be authorized and established" to work on instream flow issues and decide whether an advisory group would be desirable. SOAC evolved from that team.

SOAC is an advisory committee to Reclamation consisting of fishery biologists representing the FWS, the YN, the WDFW, and irrigation entities represented by the Yakima Basin Joint Board. Reclamation provides a fishery biologist as a liaison to SOAC. Since 1981, SOAC has provided information, advice, and assistance to Reclamation on fish-related issues associated with the operation of the Yakima Project. SOAC is the primary source (as per Court Orders) of biologically based information to the Field Office Manager. Instream flows or operations are determined by the Field Office Manager with input or recommendations provided by SOAC. SOAC is not the sole provider of input to the Field Office Manager, who will also consider information and advice from other concerned irrigation district managers, entities, agencies, or others in the process of making operational decisions.

However, Title XII sets target flows for Yakima River near Parker and Yakima River near Prosser. Note: SOAC is the entity authorized by Title XII to make recommendations to project operations for flushing and other instream flows. SOAC may bring biological concerns about operating procedures to the attention of the Field Office Manager whenever needed. Project operations maintains regular contact with and provides operations information to SOAC via the Reclamation liaison fish biologist. (See System Operations Advisory Committee, section 4.6.)

Flow Modifications for Fish

The following three operational actions are related to both upper basin and system-wide operations. These actions include use of the Kittitas Canal to bypass flows around the stretch of the Yakima River from Easton to the confluence with the Teanaway River, mini flip-flop, and flip-flop. Each of these operational schemes is designed to balance the need for irrigation water delivery with the protection of spring chinook redds in the upper Yakima River basin.

Flip-Flop Operation (CC15) -

The purpose of the flip-flop operation is to encourage anadromous salmon (spring chinook) to spawn at lower river stage levels in the upper Yakima River above the mouth of the Teanaway River, so that the flows required to keep the redds watered and protected during the subsequent incubation period (November through March) are minimized from the upper Yakima reservoir storage. Historically (pre-1980), due to irrigation demands and reservoir operations, the flows in this reach would be at a higher flow level (between 300 cfs to 1,600 cfs, 38% of the time) during the September/October spawning period, which would in turn require larger storage releases to protect redds during the incubation period. That would likely reduce the ability to maximize storage for the next season's TWSA. Pre-storage natural flows during the spawning period for spring chinook in the Easton River reach would have been in the 100 to 250 cfs range, and approximately 300 cfs in the Cle Elum River reach. In order to support the flip-flop operation, project operations drafts heavily from Keechelus, and sometimes Kachess (see mini flip-flop CC16 below), and Cle Elum Lakes on the Yakima arm to meet lower basin demands during the summer (July and August) and maintains storage in Rimrock Lake on the Naches River arm to meet lower basin demands later in the year (August 25th through October 20th). The Quackenbush Decision, October 1980, directed the release of storage for protection of redds in the upper Yakima River basin. The flip-flop operation was conceived and initiated in 1981, and has been a part of the Yakima Project operations since that time.

The flow reduction process starts September 1st and is ramped down over a 10-day period. The flow in the upper Yakima River is reduced by approximately 3,000 cfs, with the majority of the cutback taking place in the Cle Elum River, which is normally reduced to 200 cfs and then reviewed by SOAC for acceptability. The Yakima River below Easton Dam, about at 400 cfs at this time, is also reduced to the 200 cfs target level starting September 1st, although this flow level may have already been obtained during the mini flip-flop operation (see below). With this reduction of flow in the upper Yakima Reach during the fall (September and October), most lower basin demands are then met with Rimrock Lake storage releases of up to 2,400 cfs to the Naches River Arm (see Systems Operation Diagram appendix E-2).

Flip-flop operation reduces flows in the upper Yakima River during the latter portion of the irrigation season. Due to the lower water levels, a number of irrigation entities must install check dams or wing dams in the Yakima River to create enough head to divert their water supply. These structures are temporarily installed rock berms in the Yakima River in a manner consistent with issued permits, with fish passage being provided both upstream and downstream. The temporary check dams are removed following the end of irrigation season. The flip-flop operation requires that power generation water for Roza Power Plant be reduced or eliminated for brief periods of time. At times, a voluntary reduction (50 to 100 cfs) in irrigation diversions (i.e., Roza Irrigation District) is required for the flip-flop to remain functional. In normal years, expected flow in the Yakima River below the Roza Diversion Dam is in the 400 to 600 cfs range, but may drop to 300 cfs or less in below average years. The flip-flop operation does not increase flows in the Yakima River reach from the confluence of the Naches River to Union Gap (see appendix E-1). In fact, there is a reduction of flow in this reach due to reduced irrigation entitlements in September, which are more than 2,000 cfs less than August entitlements, which does not mirror the dramatic increase of flow on the Naches River. The flip-flop operation is possible because of these reduced entitlements.

Kittitas Canal Bypass -

This operation makes use of some upstream storage above Easton Diversion Dam (see appendix E-3) to supply some of the lower irrigation diversion demands in the Kittitas/Ellensburg Valley, RID, and flow demands below Roza Diversion Dam while maintaining target spawning flows in the Easton reach of the Yakima River. A portion (200 cfs) of the storage released upstream from Easton Diversion Dam is passed downstream to meet spawning flow targets in the Yakima River to its confluence with the Teanaway River. The Kittitas Canal diverts from Lake Easton (RM 202.5), parallels the river, and has a number of wasteway facilities which pass water back to the river. During the period when spring chinook are spawning in this reach (September-October), irrigation water volume is less than canal capacity, so the canal is used, along with wasteway No. 1146, to carry a portion of the flow that would normally pass over Easton Diversion Dam to meet pre-flip-flop downstream demands. Wasteway No. 1146 (RM 173.9) returns a portion of water (up to 400 cfs) diverted at Easton Diversion Dam to the Yakima River above the Swauk Creek confluence. The same canal system is also used to carry water to augment flows (up to 20 cfs) in Taneum Creek. This allows the target flow below Easton Diversion Dam (about 200 cfs) to be maintained while releases from Keechelus and Kachess are continued for downstream demand, for flow totaling approximately 1,450 cfs above the Yakima River at Easton. The amount of flow bypassed via the KRD canal ranges from about 20 to a peak of 400 cfs, with an average flow of about 300 cfs. The flows bypassed through the KRD canal begin about September 1st, being fully in place by the September 10th flip-flop date, and continue until the end of the KRD irrigation season (October 15th).

Mini Flip-Flop (CC16) -

An operations strategy commonly referred to as a mini flip-flop (see appendix E-3) is performed in years of sufficient water supply (estimated 8 to 9 out of 10 years) between Keechelus and Kachess Lakes. Heavier releases are made from Keechelus during June, July, and August to meet the upper basin demands, and releases from Kachess Lake are restrained. In the fall (September and October), heavier releases are made from Kachess to meet upper basin demands, and the releases from Keechelus Lake are reduced to provide suitable spawning flows in the Yakima River reach from Keechelus Lake to the head end of Lake Easton. Target flows for this reach are: Yakima River near Martin (KEE) 60 cfs, and Yakima River near Crystal Springs (YRCW) 60 cfs. The Kachess release is increased to 1,400 cfs to supply the continuing downstream demand of about 1,450 cfs at the Easton Diversion Dam. This 1,450 cfs demand includes 200 cfs for Yakima River instream flows at Easton, 400 cfs for the Kittitas Canal bypass, and up to 850 cfs for KRD and Cascade Irrigation District (CASID) irrigation demands. This operation is initiated the last 7 days of August and continues until October 20th.

The mini flip-flop operation cannot be performed every year. The inability to perform mini flip-flop above Easton Diversion Dam results from a short water supply forecast or a reservoir maintenance operation that would require maximum water use of Kachess Lake storage. Due to the poor hydraulic capacity of the Kachess outlet works (large volume of storage af/low head outlet works), an early June drawdown start is required to maximize storage water use. An early and maximum storage withdrawal from Kachess Lake would require higher flow releases from Keechelus during the August to October period to meet irrigation demands above Easton. This would preclude the minimizing of outflow to spawning flow targets in the upper Yakima reach below Keechelus Lake, and decrease the ability to release enough water from Keechelus Lake to protect the spring chinook redds during the November through March incubation period. To reduce possible loss of redds located in the Keechelus to Easton reach, the Easton Diversion Dam ladder has been closed in such years. With the ladder closed, the spring chinook are forced to spawn in suitable spawning areas below Easton, in areas where the flows can be managed to protect the redds during the winter months. The decision to close the Easton fish ladder and not allow spring chinook passage into the Keechelus reach needs to be made in May before the spring chinook arrive at the Easton Diversion Dam. See section 5.4 "Operation of Permanent Diversion Structures in the Yakima River Basin–Easton Diversion Dam."

Spawning Flows (CC17) -

Flows are supported by project operations to provide good quality spawning habitat for fish (usually salmonids). The flip-flop operation described above reduces flows in the upper Yakima River (see appendix E-3) for spring chinook spawning (relatively close to flow levels that would occur naturally in the spawning areas), results in the construction of redds at a lower river stage and allows for protective incubation flows (November through March) to be minimized and assured from the Yakima reservoir storage. Spawning flow levels are also provided on the Bumping River. These flow levels are determined by the Field Office Manager considering current and future water management needs, with input or recommendations provided by SOAC, irrigation district managers, Reclamation environmental staff, and others.

Where spawning activity occurs at other times and areas of the Yakima River basin, project operations considers these activities in its daily operations. While specific measures may not be taken to enhance spawning conditions in these reaches, attempts are made to minimize the impact of project operations to these spawning reaches. See "Historical Reclamation Fish-Related Operational Streamflow Targets" table 5-11. and appendix E.

Incubation Flows (CC18) -

Minimum flows are supported by project storage operations after the spawning period, which are intended to protect the eggs deposited in spring chinook, fall chinook, and coho redds in various reaches of the Yakima River, and spring chinook redds in the Bumping River. Incubation flows are set on a reach-by-reach basis depending on the salmon species. The first incubation period, for spring chinook, begins in the upper Yakima and Bumping Rivers in November, with incubation periods extending through March for all species in all spawning reaches. Incubation flows are customarily of sufficient magnitude to provide 2 inches of flowing water over the tail spill of the redds. Generally, flows between 50 to 100 percent of those provided for spawning will accomplish this. Incubation flows are determined by the Field Office Manager, with input or recommendations provided by SOAC, irrigation district managers, Reclamation environmental staff, and others.

Project operations considers site specific egg incubation needs in its daily operations. While specific measures may not be taken to enhance incubation conditions in these reaches, attempts are made to minimize the impact of project operations to the incubation activities in these reaches. See “Historical Reclamation Fish-Related Operational Streamflow Targets” table 5-11. and appendix E.

Rearing Flows (CC19) -

Sufficient flow is necessary to provide habitat for resident fish and rearing anadromous fish. The volume of rearing flows in the upper Yakima and Bumping River systems may be determined by the Field Office Manager, with input or recommendations provided by SOAC and others, considering current and future water management needs.

Where rearing activity occurs at other times and areas of the Yakima River basin, project operations takes into consideration these activities in its daily operations. Although project operations may not have a specific target flow or make storage releases to enhance rearing activity in these reaches, it does consider the constraints that these activities place on the system operations and attempts to minimize the impact of project operations to rearing fish throughout the river basin. Reference “The Yakima River Stream Catalog” Draft Copy, by Washington Department of Fish and Wildlife, March 1998, for timing of spawning, incubating, and rearing activities throughout the Yakima River Basin. See appendix E.

Ramping (CC20) -

The day to day operation of the reservoir system and hydropower facilities can cause flow fluctuations, creating the potential to strand fish and impact aquatic invertebrates that support the food chain. Reservoir or forebay maintenance drawdowns can cause fish stranding. While the project is limited in its ability to maintain stable flows in the system because of operational demands, operations seeks to minimize occurrences of fluctuation and stranding. Ramping rates have always been constrained by operational and safety concerns. Large rates of change generally are inefficient, causing flows greater than required for a short period of time and making interpretation (“reading”) of the river system difficult for operators. Several smaller changes are usually more efficient. Moreover, large rates of change, especially increases, may also endanger recreationists in the river.

As the body of biological literature developed, Reclamation recognized the need to further limit ramping rates. Since the mid-1990s, Reclamation has operated to provide a slower, gentler rate of change to implement the flip-flop operation. This currently translates to about a 225 to 300 cfs rate of flow reduction per day over a 10-day period in the upper Yakima River system. In the early years of the flip-flop operation, most adjustments were accomplished in 48 to 56 hours. Since late 1996, Reclamation has used a general ramping guideline of 2 inches per hour (stage in river) when operationally possible. Even though most concern is expressed over the possibility of stranding fish while ramping down, the guideline applies to both ramping down and up. Implementing the slower ramping rates results in increased labor cost, and during periods of flood control operations it is sometimes not possible to meet the lower ramping rates and still provide maximum flood control benefit.

Reclamation operates to the following ramping rates where controllable by project operations:

- Ramping up or down will not exceed 2 inches per hour.
- During flood control, in light of the limited impacts on the fishery resource, ramping up will be limited only by operational and safety concerns until bank full, then the 2 inches per hour limit will apply if public safety is not jeopardized.
- In the Yakima River at Easton reach, a ramping down rate of 1inch per hour will be used to help protect anadromous salmon during spawning, incubation, and rearing periods.
- If operations requires a large release of water (an increased flow fluctuation), an attempt will be made to hold the increased peak flow for 24 hours before starting ramp down.

Passage Flows (CC21) -

Flows are supported by project operations for fish movement (usually salmonids). Passage flows are flow volumes that allow fish to move un-impeded through the river system. There are three river reaches in the system with passage flow issues that are annually reviewed. Target flows for the individual river reaches are set by the Field Office Manager following consultation with SOAC and others, considering current and future water management needs. See "Historical Reclamation Fish-Related Operational Streamflow Targets" table 5-11.

River reaches for which target flows are reviewed and established, are as follows:

- Yakima River from Roza Diversion Dam to the confluence of the Naches River.

- Naches River from Tieton River to Naches River below the Wapatox Power Plant return flow.

- Yakima River from Prosser Diversion Dam to Yakima River below the Chandler Power Plant return flow.

Table 5-11.–Historical Reclamation Fish-Related Operational Streamflow Targets[4]

River Reach	Fall	Winter	Title XII Target	Power Subordination
Keechelus Outflow (KEE) from dam to Crystal Springs	60-100 cfs[2] Sep 1 - Oct 20 (1990-2000)	15-100 cfs[3, 4] Oct 21 - Mar 31 (1990-2000)		
Yakima River at Crystal Springs (YRCW) from Crystal Springs to Lake Easton	60-100 cfs[2] Sep 1 - Oct 20 (1991-2000)	30-100 cfs[3, 4] Oct 21 - Mar 31 (1991-2000)		
Kachess Outflow (KAC) from dam to Lake Easton		5-50 cfs[3] Oct 21 - Mar 31 (1989-2000)		
Yakima River at Easton (EASW) from Easton Dam to Cle Elum River	150-300 cfs[2] Sep 10 - Oct 20 (1981-2000)	80-300 cfs[3, 4] Oct 21 - Mar 31 (1981-2000)		
Cle Elum Outflow (CLE) from dam to Yakima River	150-650 cfs[2] Sep 10 - Oct 20 (1981-2000)	60-300 cfs[3, 4] Oct 21 - Mar 31 (1981-2000)		
Yakima River at Cle Elum (YUMW) from Cle Elum River to Teanaway River	400-800 cfs[2] Sep 10 - Oct 20 (1981-2000)	200-325 cfs[3, 4] Oct 21 - Mar 31 (1981-2000)		
Yakima River below Roza Diversion Dam (RBDW) from dam to below Wenas Creek	200-300 cfs minimum Jul 1 - Oct 20 (1989-1999)			300-400 cfs[5] Oct 21 - Mar 31 (1989-1999) 300-600 cfs[5] Oct 21 - Mar 15 (2000)
Bumping Outflow (BUM) from dam to American River		50-120 cfs[3, 4] Oct 21 - Mar 31 (1987-2000)		
Rimrock Outflow (RIM) from dam to YTID Diversion		15-50 cfs[6, 4] Oct 21 - Mar 31 (1990-2000)		

[4]All flows (except Title XII) are negotiated on annual basis with SOAC and at river operations meetings. Operational flows for: [2]spring chinook spawning, [3]spring chinook redd incubation, [4]this target may cause bypasses of inflow or demands upon storage, [5]passage, spawning, and incubation, [6]general aquatic needs, [7]passage and general aquatic needs, [8] fall chinook egg incubation, [9]smolt out-migration.

River Reach	Fall	Winter	Title XII Target	Power Subordination
Naches River near Naches (NACW) from PP&L Diversion Dam to below Power Return		100-125 cfs[7, 4] Oct 21 - Mar 31 (1986-2000)		125 cfs[7] Oct 1 - Sep 30 (1986-2000)
Yakima River near Parker (PARW) from SVID Diversion Dam to Granger Drain		300 cfs minimum for fish passage Mar 15 - Oct 21 (1988-1994)	300-604 cfs[4] Apr 1 - Oct 31 (1995-2000)	
Yakima River at Prosser (YRPW) from Prosser Diversion Dam to below Power Return			300-604 cfs[4] Apr 1 - Oct 31 (1995-2000)	450-1400 cfs[8] Nov 1 - Mar 31 (1995-2000) 50-200 cfs minimum for fish passage Mar 1 - Feb 28 (1958-1994) 450-1000 cfs[9] Apr 1 - Jun 30 (1994-2000)

Flushing/Pulse Flows (CC22) -

Flows are supported by project operations to facilitate the out-migration of anadromous salmonid smolts. If needed, reservoir storage releases or the bypassing of reservoir inflow can create a rapid rise in flow. These flows are intended to mimic a natural freshet, and to be useful in assisting fish out-migration. The increase has to be more than 50 percent of the base flow, peaking within 12 to 36 hours and followed by a corresponding decrease; timing is everything. Flushing/pulse flows, when deemed necessary, generally occur in the Yakima River between early April and early July, depending upon prevailing runoff conditions. The necessity for, magnitude, and timing of out-migration flushing/pulse flows are determined by the Field Office Manager, with input or recommendations provided by SOAC, irrigation district managers, Reclamation environmental staff, and others. See Memorandum Opinion Re: "Flushing Flows" No. 77-2-01484-5, dated December 22, 1994, by Judge Walter A. Stauffacher.

Power Subordination (CC23) -

Power subordination occurs when power generation is reduced or shutdown, allowing the power water diversion flows to remain in the river system to protect the fishery resources or to enhance fish passage. Currently there are three hydroelectric power plants located along the Yakima

River system which have power subordination impacts to the flow regime at their respective diversion dams:

- Wapatox Power Plant is owned and operated by PacifiCorp (parent company, Scottish Power). The Wapatox Canal has a maximum capacity of 500 cfs. This power plant diversion has a year-round natural flow right of 300 to 450 cfs. Diversion from the river (at Naches RM 17.1) is allowed up to 450 cfs so long as the flow is naturally available and the rights of senior diverters and users are satisfied, including flows to protect anadromous fish life. Reclamation is not obligated to provide storage flows at any time. During the non-irrigation season (winter) the power diversion water is informally subordinated to maintain a 125 cfs instream flow in the Naches River below the mouth of the Tieton River, as measured at the gaging station (NACW) located at Naches RM 16.8.

- Chandler Pumping & Power Plant, constructed and operated by Reclamation, uses water diverted into the Chandler Power Canal (diversion capacity - 1,500 cfs) at Prosser Dam (RM 47.1) to operate pumps to convey irrigation water across the Yakima River into the Kennewick main canal. The residual capacity remaining from irrigation needs, or if the pumps are not running for irrigation, is diverted for power production. Reclamation has the authority to subordinate Chandler Power Plant as identified in YRBWEP. Power production is subordinated to various flows throughout the year. In April through June, power is subordinated to 1,000 cfs over Prosser Dam as measured at Yakima River at Prosser (YRPW). During the remainder of the irrigation season, the subordination target is 450 cfs or the YRBWEP Title XII target flow, whichever is higher. The agreed subordination target was for 450 cfs through the non-irrigation season. For the past 2 years, however, all subordination target flows have been annually reviewed and established by the Field Office Manager, with input or recommendations provided by SOAC and others.

- Beginning in 2002, under the Conditional Final Order for Kennewick Irrigation District in the Acquavella adjudication, the flow passing Prosser Diversion Dam is to be 35 cfs higher than the Title XII flow for the period April 1 to October 31. This additional 35 cfs flow will be maintained through bypass of water that might otherwise be diverted to power generation at Chandler (April 1 through October 31). Under no circumstances will this additional 35 cfs power subordination flow call for or require storage water, nor will it jeopardize other existing water rights.

- Roza main canal, constructed and operated by Reclamation, uses up to 1,123 cfs of power water and operates year-round except for annual maintenance shutdown and ice conditions. Total diversion is limited to 2,200 cfs for irrigation, domestic supply, and power generation, with maximum power diversion of 1,123 cfs. Preference is given for irrigation. Currently, power water for electric generation at Roza Power Plant is potentially subordinated to improve fishery flows in the Yakima River below Roza

Diversion Dam (RBDW). Reclamation does not have specific direction on the authority to subordinate Roza Power Plant, but maintains an informal agreement in consultation with SOAC, Bonneville Power Administration (BPA), and others to subordinate power generation to maintain a 400 cfs minimum in the river. Reclamation operations will support a 300 cfs minimum target with water available in the river system if no power generation is occurring, but will not provide storage to maintain the 300 cfs minimum. Since the late 1990s, there have been other requests for power subordination to increase minimum flows below Roza Dam. During water year 2000, from November 8, 1999 through March 15, 2000, power was subordinated to provide a minimum flow of 600 cfs. Once, BPA agreed to cover the cost of lost power generation during the year 2000 so as not to impact the RID water supply contract. In the future, subordination target flows will be annually reviewed and established by the Field Office Manager, with input or recommendations provided by SOAC and others.

See also section 2.4.3 for additional background information on these power projects.

Target Flows -

Target flows are set for the above flow requirements (spawning, incubation, rearing, passage, power subordination) as determined by the Field Office Manager, with input or recommendations provided by SOAC, irrigation managers, and others. In addition, YRBWEP established new target flows for instream purposes to be maintained past Sunnyside and Prosser Diversion Dams using criteria based on TWSA and acquired water. Target flows are set and are to be equaled or exceeded. Due to system uncertainties such as travel time (see section 5.2.7, Travel Times), changes in runoff and changes in demand, it is technically impossible to hold a constant flow. At times, the actual instantaneous flow may be 10 percent or more below the target due to these uncertainties. River operations makes adjustments or corrections in flows as soon as possible to attain the target in these situations.

5.2.6 Hydroelectric Power Operations (CC25)

There are nine hydroelectric power plants within the Yakima basin. Of the nine power plants, only four operate with non-consumptive use, power water diversions rights (note: only three diversion dam sites - Roza, Chandler, Wapatox) out of the Yakima and Naches Rivers, the other five power plants making co-use of irrigation diversions within the irrigation districts' delivery system. The Chandler and Roza hydroelectric plants are operated by Reclamation. Pacific Power and Light Company (parent company, Scottish Power) operates the Naches, and Naches Drop hydroelectric plants (Wapatox). All of the power plants are served by water supplied via diversion dams through canal systems.

All main stem hydroelectric power plants operate as run-of-the-river plants. That is, they operate with available flows from the Yakima and Naches Rivers. Power generation at the Chandler and Roza Plants is subordinated to provide minimum fishery flows in the respective bypass reaches.

In general, power water at Roza and Chandler Power Plants is limited to any surplus amounts in excess of irrigation requirements, and in the non-irrigation season to available flows. The Wapatox hydroelectric plant has no available storage water rights. If Naches River natural flows are insufficient to maintain a 300 cfs power water diversion for the Wapatox Plant, no inflow can be stored in either Rimrock or Bumping Reservoirs. Inflow may be bypassed at the 2 reservoirs to attempt to maintain the 300 cfs natural flow minimum to satisfy the downstream Wapatox power water right. The Wapatox hydroelectric plant, having a water right priority date of 1904, has a natural flow right which is junior to most other upstream natural flow users. The Wapatox water right is senior to Yakima Project water rights, with a priority date of 1905.

5.2.7 Operations Control Points

Project operations makes use of a number of control points to monitor the system. These sites provide a window to check operations for meeting the current constraints, criteria, and objectives for the operational year. The control point data can be used as instantaneous data for set point targets or to quantify system supply demands, or use over a period of time. Current and historical data from these sites provide the knowledge needed to manage the Yakima River system with its competing demands and priorities throughout the year. The control points can be grouped into the following functions: contractual water supply, fishery flows, flood control/public safety, and hydroelectric power.

Streamflow Monitoring and Measuring -

Over time there has been an increasing demand for water use within the Yakima River basin. In order to meet this demand, project operations has had to become more efficient with management of its water. Since there appears to be no way to expand the existing water supply by new facilities or reservoirs, arguments are strong for conservation and better management of the existing water resource. To keep pace with demands, the project has had to improve its information and control system for improved water management.

An extensive real time data collection and data storage system that allows observation, monitoring, quantifying, and analysis of the river basin is in place and being updated. A remote control system is being upgraded and reinstalled at the storage reservoirs and diversion dams. These two systems will enable operations to better meet all system demands.

A hydromet system of some 60 stations has been installed over time to provide real-time data (15 minute to 1 hour intervals) on a number of parameters such as precipitation, reservoir content, streamflow, diversions, water temperature, turbidity, and weather conditions. Many of these stations can be polled from the Yakima Field Office through a radio-controlled network, and others are on a self-time reporting satellite network. For reference see appendix E showing basin wide monitoring and control points of flows included as attachments. These diagrams depict the relative positions of selected tributaries, diversions, return flows, monitoring, target, or control points and stream gaging stations.

Management and control of basin runoff; reservoirs and river operations; irrigation diversions; and liaison with fishery interests is performed and administered through the Yakima Field Office's Operations Hydrology Branch (CC26) located in Yakima, Washington. The hydrology branch is responsible for verification and review of the hydromet data. Stream gage measuring in the Yakima basin, including irrigation diversions (except for the Yakama Reservation sites) is provided largely by the Yakima Field Office's Operations Hydrology Branch. Also, the U.S. Geological Survey maintains six river or creek gaging stations in the basin.

Although records of reservoirs, rivers, and large diversions have been maintained consistently through the years, the smaller tributaries and diversions were measured only intermittently at times of desired interest. The Hydrology Branch must continue to gather current hydrologic field data as needed for hydrologic models for improved operations. Note: the Adjudication Court directed that all diversions from the Yakima, Naches, and Tieton Rivers of 1 cfs or more shall install measuring and metering devices before March 1, 1995. Diversions must be recorded and the record provided to the Yakima Field Office's Operations Hydrology Branch office on a weekly basis; this information is then provided to the WDOE.

Travel Times -

Travel times are important for river operations in order to plan and maintain balanced instream system flows at target control points. The following table represents the elapsed time (travel time) for releases made at reservoirs to pass through the river system and arrive at the control point (river gaging station). All values (hours) are average times assuming that the river reach has a fully wetted perimeter (i.e., it is not being charged up initially following a low flow condition). The flow levels represent the "total" low, average, and high flow release per reservoir during the irrigation season, and are not meant to depict flood flow travel times. River operations should note that in table 5-12. times are indicators and not absolute travel times. During day to day operations, a hydromet plot of multiple-day real time gaging station data will provide a more accurate representation of current travel time requirements.

Table 5-12.–Yakima Basin Travel Times – Elapsed time in hours during irrigation season.

Release point	Flow Levels cfs	EASW	YUMW	ELNW	UMTW	CLFW	TICW	NACW	PARW	YRPW
Keechelus	low - 400 average - 900 high - 1500	5.5 3. 2.5	15.5 10.5 9.	27. 18. 15.	41. 29. 23.	- - -	- - -	- - -	58. 41.5 32.	82. 63.5 52.
Kachess	low - 300 average - 800 high - 1200	1.0 .5 .5	12.5 9. 7.5	25. 16.5 14.	39. 28. 23.	- - -	- - -	- - -	56. 42. 33.5	80. 64. 53.5
Cle Elum	low - 500 average - 2000 high - 3200	- - -	4.5 2. 1.5	15. 7.5 7.	28.5 15.5 14.	- - -	- - -	- - -	44. 22.5 20.5	68. 44.5 40.5
Bumping	low - 300 average - 700 high - 1100	- - -	- - -	- - -	- - -	5.5 5. 4.5	- - -	12. 11. 10.5	21. 17. 15.5	45. 39. 35.5
Rimrock	low - 500 average - 1400 high - 2200	- - -	- - -	- - -	- - -	- - -	1.5 1. .5	5. 4. 3.5	12. 9 8.5	36. 31. 28.5

(Last update of Travel Time Curves – 3/21/79 by Fred L. Nacke)

Yakima River near Parker WA (Below PARW) -

The major control point for operation of the Yakima Project is the Yakima River near Parker stream gage (PARW, RM 103.7), which is just downstream of Sunnyside Diversion Dam. Yakima Project operations for PARW are keyed to meet the irrigation entitlements above Sunnyside Diversion Dam, maintain instream minimum target flows for the fishery resources, and provide maximized flood control benefits for the Yakima River basin. When the system is on storage control, diversion demands below Parker are met by return flows, flows passing Parker, and tributary inflows below Parker. The instream minimum target flows at Parker are related to the fisheries resource during the April through October period, and the maximum target flows relate to flood control operations, November through June.

Since April 1995, the Yakima Project has been operated to provide streamflows over Sunnyside as specified in the YRBWEP legislation. These flows are based on the TWSA and range from 300 to 600 cfs (see YRBWEP Title XII Target Flow table 5-10) for the period April1st through October 31st. Reclamation prepares monthly TWSA forecasts from March through July, or, if conditions warrant, later into the irrigation season, which ends in mid-October. These forecasts are the basis for determining the adequacy of the TWSA to meet irrigation water entitlements stipulated in the Decree, to assist in deciding the amount of prorationing, if any, that may be necessary and for determining Title XII flow targets.

To meet system water demand requirements, including instream flows at Parker, river operators must consider many factors. The July through August flow travel time for normal operational releases between the reservoirs and the control point at Parker ranges from a minimum of

10 hours from Tieton Dam to over 40 hours from Keechelus Dam (see travel time table 5-12.). The intervening river reaches are affected by many diversions, return flows, and natural inflows. These add to the uncertainty and difficulty of maintaining a precise target at Parker. After storage control the system will normally develop a diurnal 80 to 100 cfs cycling effect from evaporation and irrigation practice, and a weekly increase (+/- 200 cfs) in return flows due to weekend irrigation practice, which greatly effects the flow available at PARW. Title XII target flows permit fluctuations up to 35 percent from the specified target for a period, not to exceed 24 hours, at Sunnyside Dam.

To remove some of the uncertainty in the system and to better meet target flows, irrigation districts and other diverters of 1 cfs or greater are to verbally inform the Yakima Project operator 48 hours in advance of any planned diversion or change in diversion (by Judicial Order in State of Washington vs. Acquavella). Unplanned changes in diversions are to be reported as soon as possible after the change has been made. Regular contact is maintained with the 5 major irrigation districts (holders of 82% of TWSA entitlements) diverting above Parker.

Yakima River Near Prosser WA (YRPW) -

The prime control point for operation of the lower Yakima River is the Yakima River near Prosser stream gage (RM 46.3), which is just downstream of Prosser Diversion Dam. Since 1995, the Yakima Project has operated to provide streamflows for fishery resources at YRPW as specified in YRBWEP. Again, these flows are based on the TWSA and range from 300 to 600 cfs (see YRBWEP Title XII Target Flow table 5-10.) for the period April 1st through October 31st. The YRBWEP target flow requirements below Prosser Diversion Dam are the same as those for the Yakima River near Parker. However, streamflow must not decrease by more than 50 cfs from the target flow.

Other fishery resource flow issues for the gage near Prosser include target flow requirements for ramping rates, incubation flows, passage flows, flushing/pulse flows, and power subordination. Ramping rates are a year around issue, passage flows and flushing/pulse flows are predominantly an April through June issue, and fall chinook egg incubation flows involve the November through March period. In 1995, Reclamation agreed to power subordination levels that provide for 1,000 cfs minimum at YRPW for April through June, and 450 cfs minimum during July through February. The power subordination level of 450 cfs takes precedence over YRBWEP flows of 300 or 400 cfs. The target flows for the other flow issues are annually reviewed and established for each time period by SOAC and the Field Office Manager.

Diversion demands of the lower Yakima River, from the Yakima River near Parker to Wanawish (Horn Rapids) Diversion Dam, are predominantly met by return flows and flows passing YRPW gage. If, after power subordination is fully implemented, YRBWEP Title XII flows are not satisfied, flow releases from storage are required to reach the target minimum flows.

Other Minimum Flow Control Points -

Minimum target flows are set at many other locations along the Yakima and Naches Rivers (see table 5-11.). Target flows are to be equaled or exceeded. These flows are determined through various means and are coordinated via SOAC and the Field Office Manager.

Flood Control Points (CC5 & 6) -

Several gages along the Yakima and Naches Rivers are also used as control points for flood control activities in the Yakima basin. Given the amount of basin runoff above the reservoirs, the storage capacity at the reservoirs, and their outlet capacities, the Yakima Project attempts to control the downstream flows to below damaging levels. Observed flood stages at these locations are listed in table 5-13. below.

Table 5-13.–Yakima Basin River Control Points - Used during flood control operations.

River forecast point	Bankfull stage	Flood stage	Moderate flooding	Major flooding	Record crest
EASW Yakima River at Easton		50.3 ft			
YUMW1 Yakima River at Cle Elum	8.5 ft	9.0 ft	9.5 ft	12.5 ft	12.50 ft Nov. 14, 1906
ELNW1 Yakima River at Ellensburg	32.0 ft	34.0 ft	37.0 ft	39.0 ft	36.76 ft Feb. 9, 1996
NACW1 Naches River near Naches	15.0 ft	17.0 ft	18.0 ft	20.0 ft	22.90 ft Dec. 23, 1933
PARW1 Yakima River near Parker	9.4 ft	10.0 ft	12.0 ft	14.0 ft	16.21 ft Feb. 9, 1996
KIOW1 Yakima River at Kiona	12.5 ft	13.0 ft	15.0 ft	17.4 ft	21.57 ft Dec. 23, 1933

(Control points & data via National Weather Service - Northwest River Forecast Center) Note Reclamation control point data.

5.3 Operational Functions of Reservoir Storage in the Yakima River Basin

The water storage facilities used to supplement the unregulated flow from the Yakima River are Keechelus, Kachess, Cle Elum, Rimrock, Bumping Lakes, and Clear Creek. The five major storage facilities/reservoirs store runoff during the winter and spring/summer seasons for later release to supply irrigation demands during the low flow periods of runoff in the summer/fall seasons. The total storage of the 5 major storage reservoirs is a little over 1 MAF. It should be noted that the combined total storage of the five major reservoirs are operated in a coordinated manner to provide the needs of the system as a whole. The releases from each reservoir are balanced to meet system-wide demands in conjunction with natural runoff and return flow available in the basin. No one reservoir is designated to supply the needs of one particular area, irrigation district, or division. The following table 5-14. provides some basic information about each of the five major storage reservoirs, followed by a summary of the important operational aspects of each reservoir and the part each plays in managing the Yakima River basin water supply. (CC29)

Table 5-14.–System Storage Capacity & Average Annual Runoff. (Plus TWSA's Sept. 30th Historical Storage)

Reservoir	Drainage Area (mi.^{2})	Capacity (af)	Ave. Annual Runoff (af)	Ratio of Ave. Runoff to Capacity	Sept. 30 Min. Historical Storage (af)	Sept. 30 Ave. Historical Storage (af)	Sept. 30 Max. Historical Storage (af)
Keechelus	54.7	157,800	244,764	1.5:1	4,800	40,500	126,900
Kachess	63.6	239,000	213,398	.9:1	20,100	107,200	227,200
Cle Elum	203.0	436,900	672,200	1.5:1	12,900	118,000	359,500
Bumping	70.7	33,700	209,492	6.2:1	2,400	7,900	24,600
Rimrock	187.0	198,000	367,966	1.8:1	200	74,500	145,100
System	579.0	1,065,400	1,707,820	1.6:1	51,700	357,500	660,200

(Period of Record = 1920-1999)

Sixth Reservoir (snowpack) -

Because only 30 percent of the average annual total natural runoff can be stored in the storage system, the Yakima Project is very dependent upon the timing of spring/summer runoff (snowmelt and rainfall). The early spring/summer natural flow is utilized to supply most river basin demands through June in an average year. The majority of spring/summer runoff is from snowmelt, therefore snowpack is often called the 6th reservoir. In most years, the five major reservoirs are operated to peak storage in June (average mid-June, period of record 1940-1999), about the same time the major natural runoff ends.

Keechelus Lake -

Keechelus Lake and Dam, on the Yakima River 10 miles northwest of Easton, is an earthfill dam, situated at the lower end of a natural lake, that forms a reservoir with a capacity of 157,800 acre-feet, with 152,170 acre-feet available for use. Keechelus Lake is operated to meet irrigation demands, flood control, and instream flows for fish. Keechelus storage is used in conjunction with the rest of the system to provide a portion of the water supply to meet demands from Keechelus Dam to Sunnyside Diversion Dam. A larger portion of the annual runoff to Keechelus Lake, however, is used, along with that of the Kachess River, to satisfy upper basin demands. Keechelus also provides some carryover storage in normal water years. The prime flood control season extends from mid-November through mid-June. Irrigation demands are met by releases from Keechelus either through bypassed reservoir inflows (beginning in mid-March) or stored water releases. When the project is on storage control, diversions above Easton, including those for KRD, are served primarily from Keechelus through late August. During September and October those diversions are satisfied primarily out of Kachess.

Outflows from Keechelus follow an annual pattern of relatively low flows during winter and relatively high flows during the April through late August irrigation season. Beginning in late August, during mini flip-flop, Keechelus releases are reduced to meet a 60 cfs target streamflow in the Yakima River at Crystal Springs. This operation functions to keep downstream flows low so that spring chinook salmon will spawn in areas that can be kept watered throughout the winter incubation season. In October, after spring chinook spawning is complete, streamflows are reduced still further, generally to around 30 cfs (or the SOAC recommended incubation flow) in the Yakima River at Crystal Springs. The 30 cfs represents a Keechelus release of about 15 cfs with the remaining 15 cfs supplied from inflows between Keechelus Dam and Crystal Springs. If there were no inflows between Keechelus Dam and Crystal Springs the full 30 cfs would be released from Keechelus Lake. This operational scheme attempts to keep all the spring chinook redds under water throughout the winter in the reach from Keechelus Dam to Easton Dam without jeopardizing irrigation storage supplies. This operation is continued until reservoir releases are increased either due to flood control or to meet irrigation demand.

The dam is equipped with an overflow crest spillway capable of passing 8,000 cfs at elevation 2520.90 feet. The main outlet works has a single slide gate (8.5' x 8.5') with a 7 foot maximum gate opening capable of releasing 3,000 cfs, but the normal maximum would be 1,500 to 1,700 cfs. This gate (sill elevation 2426.90 ft.) has a minimum gate opening of 4 inches in the high head mode (over 33') and 1.5 inches opening the under low head mode (under 33'). Located in the same outlet works is a 20-inch valve at invert elevation of 2446.67 feet, which at 15 foot of head will bypass approximately 25 cfs through a 22-inch-diameter pipe installed in the outlet conduit to bypass minimum flows for fishery and stream enhancement when the main outlet gate is closed. The ramping rate for operations at Keechelus is 2 inches per hour as measured at the dam's outflow gage.

In mid-1998, it was determined that dam safety deficiencies existed at Keechelus Dam due to the potential for dam failure from piping and/or internal erosion of embankment materials. A reservoir operating restriction to elevation 2510 feet was imposed, together with increased monitoring and surveillance, pending implementation of corrective actions. This operating restriction limits storage to 140,920 acre-feet. The reservoir can be operated above elevation 2510 feet only for the control of large flood events.

Kachess Lake -

Kachess Lake and Dam, on the Kachess River 2 miles northwest of Easton, is an earthfill dam, situated at the lower end of a natural lake, that forms a reservoir with a capacity of 239,000 acre-feet, with up to 222,000 acre-feet available for use. Kachess Lake is operated to meet irrigation demands, flood control, and instream flows for fish. The flood control season extends from mid-November through mid-June. Flood space control releases are normally minimal due to the poor refill ratio of .9 to 1. A refill ratio of less than 1 to 1 means a reservoir will not fill even in an average year if it starts the year empty. Kachess storage is used in conjunction with the rest of the system to provide a portion of the water supply to meet demands on the Yakima River from

Easton Diversion Dam to Sunnyside Diversion Dam. A larger portion of the annual runoff to Kachess Lake, however, is used along with that of the Keechelus Lake and Cabin Creek to satisfy upper basin demands. Kachess Lake provides some carryover storage in good water years. Upper basin irrigation demands are met by releases from Keechelus either through bypassed reservoir inflows (beginning in mid-March) or stored water releases. When the project is on storage control, diversions above Easton, including those for KRD, are still served primarily from Keechelus through late August, or the start of mini flip-flop. From the start of mini flip-flop and flip-flop, the diversions above Easton and up to 400 cfs of downstream diversion, during September and October, are provided primarily out of Kachess.

Besides supplying a large portion of the system-wide irrigation demands, storage at Kachess Lake is needed to meet fishery resource's winter (incubation and rearing) minimum target flows from Yakima River at Easton to the confluence of the Yakima and Teanaway Rivers. In addition, the high storage demand when the reservoir is operated to meet multiple instream flows, significantly reduces the ability of the reservoir to refill the following season. This is especially true of Kachess Lake, because the average annual runoff is less than reservoir capacity. Therefore, the reservoir does not fill every year even under normal runoff conditions. Kachess minimum outflow during the winter is 5 to 8 cfs (equivalent to gate leakage) unless greater releases are needed for support of the Yakima River target flows.

The dam is equipped with a gated spillway (sill elevation 2254.00 ft.), consisting of 1 radial gate (50' x 8') with capacity of 4,000 cfs at elevation 2262.00 feet. The regulating outlet works has 3 slide gates (4.5' x 8.0') with an 8.0 foot maximum gate opening capable of releasing 3,690 cfs at full lake elevation (2262.00). These gates (sill elevation 2192.75 ft.) have a minimum gate opening of .17 foot and are the main release points if supporting spawning and incubation flows in the Yakima River. Located in the same outlet works is an 18-inch butterfly valve at invert elevation of 2195.92 feet, which at 25 foot of head and 100 percent gate opening, bypasses approximately 35 cfs into the outlet conduit, through the valve installed in the outlet works downstream of the main gates. When the main outlet gate is closed, and the auxiliary low flow bypass valve is being used, it is only capable of providing minimum flows for fishery and stream enhancement in the Kachess River. Kachess Dam has no fish passage facilities. The ramping rate for operations at Kachess is 2 inches per hour as measured at the first gage below the dam.

Cle Elum Lake -

Cle Elum Lake and Dam, on the Cle Elum River 8 miles northwest of the town of Cle Elum, is an earthfill dam, situated at the lower end of a natural lake, that forms a reservoir with a capacity of 436,900 acre-feet, with 427,930 acre-feet available for use. Cle Elum Lake is operated to meet irrigation demands, flood control, and instream flows for fish. The prime flood control season extends from mid-November through mid-June. Cle Elum Lake regulates about 20 percent of the entire runoff above Parker and is the largest storage facility in the system. It is, therefore, the main resource for meeting the large irrigation demands in the lower basin. The heaviest storage releases for irrigation are during the months of July and August and it's normal for the main gates to reach hydraulic capacity in mid-August. Cle Elum also provides the majority of carryover storage in normal water years.

In most years, 40-50 percent of the spring chinook redds in the upper Yakima River basin are located in the Cle Elum River and in the Yakima River immediately upstream and downstream of the confluence of the Cle Elum and Yakima Rivers. These factors lead to conflicting needs for the operational releases from the reservoir. The lower basin diversion demands during the summer months (July and August) are mostly met from Cle Elum releases. During flip-flop the majority of the summer release (3200 cfs +/-) is cut back to a minimum flow level (200 cfs) that is adequate to support both spawning and irrigation demands on the upper Yakima River system. The larger portion of the lower basin diversion demands during the spring chinook salmon spawning period (September and October) are met from Rimrock releases. This allows Reclamation to minimize Cle Elum releases to meet a target flow (normally 150 cfs) in the Cle Elum River during the winter for spring chinook incubation and early rearing.

The dam is equipped with a gated spillway (sill elevation 2223.00 ft.), consisting of 5 radial gates (37' x 17') with capacity of 40,000 cfs at elevation 2240.00 feet. The main outlet works has 2 slide gates (5.0' x 6.5') with a 6.2 foot maximum gate opening capable of releasing 4,600 cfs, but August normal maximum would be 3,400 cfs +/-. These gates (sill elevation 2112.25 ft.) have a minimum gate opening of 0.10 foot and are the main support for the spawning and incubation flows. Located in the same outlet works are two 14-inch gate valves at invert elevation of 2127.09 feet, which at maximum head will only bypass 45 cfs each into the main outlet conduit when the main outlet gates are closed. Note that this is not enough flow to support the normal spawning or incubation flows in the Cle Elum River reach. Maintenance work to the inlet works tunnel or guard gates requires stop-logging at the headend of the outlet works. Currently this would allow no flow into the downstream river. As such, this type of required maintenance is attempted only when the lake is above spillway crest (elevation 2223.00 ft.) or pumping to maintain instream flows would be necessary. Cle Elum Dam has no fish passage facilities. The ramping rate for operations at Cle Elum is 2 inches per hour as measured at the first gage below the dam.

Bumping Lake -

Bumping Lake and Dam on the Bumping River about 29 miles northwest of the town of Naches is an earthfill dam, situated at the lower end of a natural lake, which forms a reservoir with a capacity of 33,700 acre-feet, with 31,220 acre-feet available for use. The average annual runoff at Bumping Lake is much more than the existing reservoir capacity, allowing the reservoir to fill every year. It is normally operated in the flood operations mode during the spring/summer period, except for extreme water-short years or multiple short years in a row. Depending on the timing of the runoff, the reservoir can be brought up to full pool a number of times each year. The facility is used to supplement water supply for demands in the upper Naches River during summer months and during the winter months may be called upon to bypass inflow to support the Pacific Power & Light's (PP&L) Wapatox power diversion right. Heavy drawdown of storage for summer irrigation demand, normally starts in August and continues into early September. Bumping Lake is not used as a carryover facility, but is operated to provide 6,000 to 9,000 acre-feet of end-of-season storage needed to maintain winter incubation flows in the Bumping River.

During the early September through late October spawning period, the reservoir's outflows are kept under 200 cfs, in order to minimize the required releases for the incubation and rearing period from storage. Natural inflow to Bumping Reservoir often drops below 35 cfs and requires supplementation from the carryover storage to provide winter minimum target flows. During the winter incubation and rearing period, instream flows below Bumping Dam are kept at a minimum target of 50 cfs or more depending on past spawning flows and are coordinated between SOAC and the Field Office Manager.

Bumping Dam is equipped with an overflow crest spillway (elevation 3426.20 ft.) capable of passing 3,400 cfs at a reservoir elevation of 3429.00 feet. The main outlet works has 2 slide gates (4.5' x 5.0') with a 5.0 foot maximum gate opening capable of releasing 1,240 cfs, but August normal releases would be in the 500 to 700 cfs range. These gates (sill elevation 3389.00 ft.) have a minimum gate opening of 0.10 foot and are the only support for the spawning and incubation flow releases as there is no auxiliary low flow bypass in Bumping Dam. Any maintenance work to the inlet works or guard gates requires stop-logging at the intake of the outlet works or closing the main gates to work in the outlet tunnel. This would allow no flow into the downstream river. As such, this type of required maintenance is attempted only when the lake is above spillway crest (elevation 3426.20 ft.) or pumping to maintain instream flows would be necessary. Bumping Dam has no fish passage facilities. The ramping rate for operations at Bumping is 2 inches per hour as measured at the first gage below the dam.

Rimrock Lake -

Rimrock Lake and Tieton Dam are on the Tieton River about 40 miles northwest of Yakima. Tieton Dam is an earthfill structure with a concrete core wall that forms a reservoir with a capacity of 198,000 acre-feet, with 197,800 acre-feet available for use. Rimrock Lake is operated to meet irrigation demands, flood control, and instream flow for fish. The prime flood control season extends from mid-November through mid-June. Flood space control releases of 2,700 cfs or greater during the winter could impact residents along the Tieton River. Ice Watch (CC25) is conducted during the colder, freezing periods of winter weather (January, February, and March). When the lake surface is capable of freezing or has frozen solid, in order to prevent damage to the spillway structure and gates, the lake elevation is held below 2900.00 feet until the freezing danger is past. Releases (500 to 700 cfs) are made during the summer months to meet demands on the Tieton and Naches Rivers below Tieton Dam, downstream to the confluence of the Naches and Yakima Rivers. In support of the flip-flop operation during the fall months (September and October), much higher releases (up to 2,700 cfs) are also made to meet lower Yakima River basin irrigation needs, thereby allowing the releases from the upper Yakima arm reservoirs to be reduced to provide reduced spawning flow. Rimrock Lake will provide good carryover storage in normal or better water years. In any operation plan, unregulated flows in the

Naches River system must be made available and bypassed when required to fulfill the natural flow rights for PP&L's Wapatox power diversion. Support of maintenance work requiring river ford access to the canal or fish screens at Yakima-Tieton Diversion Dam can require outflow reductions at Tieton Dam.

Fishery interests support a minimum storage pool of from 10,000 to 30,000 acre-feet (preferably greater than 30,000 acre-feet) to maintain the viability of the fisheries resource in Rimrock Lake. With this in mind, carryover storage in Rimrock Lake is maximized. At a minimum, 30,000 acre-feet is the target for September 30th. Winter minimum instream flows below Rimrock have been between 15 and 50 cfs during the past few years (1996-2000).

Tieton Dam is equipped with a spillway weir controlled by six 65 foot by 8 foot floating drum gates (down position, invert elevation 2918.00 ft.), with capacity of 45,700 cfs at elevation 2928.00 feet. The main operating outlet works has two 60-inch-diameter jet-flow gates (invert elevation 2721.50 ft.) and with a 95 percent maximum gate opening. These gates are capable of releasing 2,760 cfs at normal full lake (elevation 2926.00 ft). When flow demands require operation of both gates at the same time, a minimum 40 percent (2 ft.) gate opening is maintained to allow rock passage. When only operating a single gate, the minimum opening is 4 inches or 5 percent, resulting in a 15 to 20 cfs discharge. These gates are the only support for minimum instream winter flow as there is no auxiliary low flow bypass located in Tieton Dam. Any maintenance work to the inlet works (sill elevation 2766.00 ft.) or guard gates requires stop-logging at the headend of the outlet works to close the outlet tunnel. This allows no flow into the river downstream. Therefore, this type of required maintenance is attempted only when the lake is above spillway crest (elevation 2918.00 ft.) or pumping to maintain instream flows would be necessary. Tieton Dam has no fish passage facilities. The ramping rate for operations at Rimrock is 2 inches per hour as measured at the first gage below the dam.

Clear Creek Lake -

The supplementing of irrigation flow and the regulation of Clear Creek Lake is negligible when considering its small storage capacity (5,300 af) and its location above Rimrock Reservoir. However, in short water years, it is possible to provide some benefit to the downstream storage demands to offset irrigation and fishery minimum storage requirements in Rimrock Lake. In normal runoff years, Clear Creek Lake is operated to maintain an elevation greater than 3011.40 feet for project uses including fish passage and recreation. Inflow and outflow are essentially equal and most all flow passes over a spillway weir crest at elevation 3011.00 feet. For the past 20 years, one 36-inch slide gate has been kept open 6 inches to prevent the outlet gate area from silting up. From mid-August to October 5th, Reclamation attempts to hold the lake at elevation 3011.40 feet for most effective fish ladder passage and to maintain stable downstream spawning flow. In years of late season high volume runoff, this elevation is nearly impossible to hold, unless large releases are made through the dam's slide gates. This is undesirable because the fish are attracted by the high flow. They are not attracted to the spillway flows which supplies the fish ladder passage.

The majority of operations functions occurring at Clear Creek Lake involve a short water year when it is possible to provide some benefit to the low storage pool in Rimrock Lake. The use of Clear Creek Lake storage occurs when Rimrock's September 30th storage drops below 34,000 acre-feet. Advance notice of intent to drawdown the lake must be given by August 10th to the United States Forest Service so that timely notification may be given to the recreation interests to protect their lake facilities. After October 5th and concluding by October 20th, it is possible to transfer 2,200 acre-feet of storage to Rimrock Lake for operational use by irrigation or fishery minimum pool demands. Increased outflows from the reservoir do not start until after October 5th because of the risk of kokanee spawning in the higher outflows. After October 20th, Clear Creek Lake can be refilled by closing the outlet gates, but lows are held below the dam to incubation flows based on September spawning flows. (Note: due to the limited storage available to supplement irrigation flows and providing only minimal support to maintain the desired low storage pool [10 KAF to 30 KAF] in Rimrock Lake, the regulation of Clear Creek Lake [upstream from Rimrock Lake] may not be acceptable to current fishery interests, due to the spawning and incubation risk created in the North Fork of the Tieton River by releases from the lake.)

Storage Carryover -

During the summer/fall period of operations, it is desirable to maximize storage carryover by end of irrigation season (October 21st). The Yakima storage system is designed only to store the current year's spring/summer runoff and deliver it to meet irrigation demands in July through October. If there is only minimal storage (52 KAF) left on October 21st, then the winter and spring/summer periods of operations require a tighter control over the reservoir releases, lower base river flows, and variability during these time periods. A maximized storage carryover helps to ease those operations and meet demands during a dry year. The impacts of the drought year of 1977 were reduced because of favorable carryover storage from 1976. The 1994 drought was disastrous because there was virtually no carryover after the drought years of 1992 and 1993. A good carryover also helps assure sufficient spring chinook incubation flow below the upper Yakima main stem dams.

5.4 Operation of Permanent Diversion Structures in the Yakima River Basin

The following list summarizes some of the operational aspects of each permanent diversion structure on the Yakima basin main stem tributaries and the part each plays in the management of the basin water operations.

Lake Easton Diversion Dam -

Lake Easton Diversion Dam (Yakima RM 202.5), is a small concrete gravity dam with an ogee-overflow-weir spillway section across the central portion of the dam and is controlled by one 64 foot by 14.5 foot drum gate with a design capacity of 13,000 cfs. The dam also has 2 sluiceways, 1 in each side of the dam below the spillway crest (elevation 2165.80 ft.), with each of these outlets (invert elevation 2135.00 ft.) controlled by a 4.8 foot by 6.0 foot gate. The vertical slot fish ladder is located on the left abutment. An irrigation diversion check structure (hydraulic height 43 ft.), with the Kittitas main canal headworks (capacity 1,320 cfs) located in the right abutment, is operated and maintained by KRD. Irrigation diversion is provided from April 20th through October 15th. The diversion dam creates a lake (N.W.S. 2180.30 ft.) for diversion head (canal invert elevation 2170.0 ft.) rather than storage, but in water-short years there is 2,000 to 3,000 acre-feet of storage that is available for irrigation demands during the last days of irrigation season. Yakima Project operations coordinates closely with KRD to accomplish a variety of operational needs including irrigation, fisheries, flood control, recreation, and maintenance to structures. Yakima Project operators monitor streamflow in the Yakima River at Easton closely because this area is vulnerable to flooding; the river reach below Easton is considered to be high value fish habitat for spawning and rearing, and the reach can become a bottleneck in terms of passing irrigation flows to areas downstream. During the past 2 years gate manipulations at Easton have ensured that ramping rates do not exceed 1 inch per hour. This minimizes adverse impacts of operations to the river reach below Easton.

Operations/activities at Easton Diversion Dam have historically been an issue to biologists, so the following operation for maintenance is described. The 64-foot-wide drum gate (movable crest) at Easton Diversion Dam is inspected once a year, at the end of the irrigation season. If the need for maintenance or repair is indicated, the work is normally scheduled for the early winter period. Normal winter operation maintains the drum gate in the down position until April 1st. The inspection requires the water level to be taken below the hinge (elevation 2164.90 ft.) of the drum gate. This is accomplished by lowering the lake elevation to the crest of the lowered drum gate (elevation 2165.80 ft.) and then opening the sluice gates to lower the lake to elevation 2164.40 feet. This provides another 6 inches below the hinge level, to prevent leakage into the drum gate float chamber. If possible, holding Lake Easton to a minimum elevation of 2164.40 reduces the risk of sediment transfer to the lower river from rainfall on the lower lake bed. After the inspection, the sluice gates are slowly closed to allow the lake elevation to rise and pass flow over the lowered drum gate crest (elevation 2165.80 ft).

In 1998, fishery biologists recommended that Reclamation and KRD attempt a timely, more fish friendly fill of Lake Easton Irrigation Diversion Dam pool that would be completed by April 1st. Reclamation efforts to implement this recommendation showed only minimum flow fluctuations in the river below the dam, and minimized turbidity changes caused by the manipulation of Easton Dam drum and sluice gates. This operation requires dropping the lake elevation down to the elevation of the drum gate in the lowered position by use of the sluice gates. (Note: the initial opening of the north/left and south/right sluice gates are checked for silt movement and turbidity activity by the KRD dam tender, and if necessary, by the FWS fisheries biologist and Reclamation fisheries biologist.) At the start of the filling operation, the lake is lowered by increasing the outflow slowly through the sluice gates. When the lake elevation reaches approximately 2165.80 feet, the drum gate float chamber is allowed to fill, floating the drum gate to elevation 2177.95 feet or more, as per the gate position indicator. The sluice gates are then cut back or closed a minimal amount to start filling the lake. Over the next few days the lake is slowly filled, while the majority of the inflow to the lake is bypassed to the river by the north/left sluice gate. When the lake has risen to full elevation or high enough to pass flow over the drum gate in the raised position, the north/left sluice gate is slowly closed to force all the flow over the floating drum gate. The ramping rate for this operation is 1 inch per hour on the declining flow as measured at Yakima River at Easton, which will minimize overall flow fluctuations in this reach of the Yakima River. This operation is the current or preferred method of filling Lake Easton Diversion Dam pool if the pool has not been filled by a large runoff event occurring in late March.

When the sluice gates are opened sediment flushes to the area downstream, which is spring chinook spawning habitat. Normally, the volume of sediment moved only creates a slight discoloration to the flow lasting for a period of minutes. In order to minimize this small movement of sediment, the sluice gates are opened periodically throughout the year to remove sediment incrementally. The sluice gates are opened in spring, when flows are high, so that the sediment can be dispersed, and then again in August, just prior to flip-flop when flows over Easton are still relatively high. As a result, when the gates are opened during the fall maintenance activity, the instantaneous movement of sediment load is very low to nonexistent. The past 2 incidents of heavy sediment movement through the dam's sluice gates (sluiceway invert elevation 2135.0 ft.) to the downstream spawning habitat occurred during unusual circumstances, with the pool drawn down below elevation 2160.5 feet to facilitate maintenance on the dam and fish passage (fish ladder flow invert elevation 2162.0 ft.), coupled with a significant rainfall event on the dewatered lake bottom. The rainfall's runoff destabilized the normally water covered lake bottom below elevation 2166.8 feet and moved silt into the reduced flow channel of the lowered lake, passing it through the sluice gates to the downstream reach. Attempts will be made to minimize future low pool operations, below elevation 2164.40 feet, for maintenance functions, by stop-logging the fish passage or other cofferdam methods for repair and maintaining the upstream functionality of Easton Diversion Dam.

Operation of the fish ladder at Easton Diversion Dam varies from year to year based on the water supply outlook. Reclamation, in consultation with SOAC, decides in May whether to keep the ladder open for spring chinook. This decision is made as soon as the first chinook arrives at the Roza Fish Facility. The decision is based on current TWSA. If water supply forecasts indicate that mini flip-flop can be executed during the coming fall, the ladders are kept open. An early decision is necessary to prevent a loss of redds in the fall. If chinook are allowed to spawn above Easton (i.e., the ladders are kept open), but mini flip-flop is not operationally possible, then a large proportion of the eggs are lost due to low streamflow conditions during the subsequent incubation period. This is why the ladder is sometimes closed and the spring chinook are forced to spawn in the suitable spawning areas below Easton. Prior to 1997, mini flip-flop was possible only about 50 percent of the time. The Kachess Dam outlet structure has since been modified and now mini flip-flop is estimated to be possible 8 to 9 years out of 10. The ladder at Lake Easton is open in all years from October 20^{th} through mid-May. This fish ladder will operate at lake elevations between 2165.8 and 2180.3 feet.

When the KRD canal is diverting water, the fish-screen fish return passage is normally bypassing 80 cfs to the river just below the right abutment. When reducing the flows to spawning targets of 150 to 300 cfs at Yakima River at Easton, it will improve attraction to the fish ladder on the left abutment if the fish bypass flows are reduced to 40 cfs. If the 80 cfs is continued to be bypassed on the right side, the fish are attracted to cascading flows with no upstream passage. Normally, with an Easton spawning target of 200 cfs, the ladder will be passing approximately 80 to 120 cfs for upstream passage, 40 cfs on the fish bypass, 5 cfs for dam drum gate operation, 15 cfs for drum gate seal leakage, and from 60 to 20 cfs overflow at the drum gate crest. At these low flows, passage and attraction water flows through the fish ladder.

Ellensburg Town Canal Diversion Dam -

The Ellensburg Town Canal Diversion Dam (Yakima RM 161.3) is a concrete fixed crest weir (elevation 1613.35 ft.), with a fish ladder located on the right abutment. The irrigation diversion check structure (hydraulic height 3.35 ft.) is located approximately 7 miles northwest of Ellensburg, Washington and is owned, operated, and maintained by Ellensburg Water Company. This diversion (left abutment) provides water to about 12,000 acres in the Ellensburg Valley, serving the Town Canal and Olson Ditch during the irrigation season (mid-April through mid-October), and also provides supplemental water to the City of Ellensburg through a supply pipe about 300 feet downstream of the headworks. From April through October a maximum of +/- 230 cfs is diverted for irrigation and fish screen operations. From November through March water may be diverted for stock watering and/or city M&I water.

Roza Diversion Dam -

Roza Diversion Dam (Yakima RM 127.9) is a 486-foot-wide, concrete gravity ogee-weir-type (elevation 1205.00 ft.) with a variable water surface elevation (N.W.S. 1220.60 ft.) controlled by two 110 foot by 14 foot motor operated (float controlled) roller gates. It is located on the Yakima River about 12 miles north of Yakima. This irrigation and hydroelectric power diversion check structure (hydraulic height 34.0 ft.) is owned by the United States, operated and maintained by Reclamation, and provides water diversion of up to 2,200 cfs to the Roza main canal, of which up to 1,350 cfs design capacity, (actual diversion 1,260 cfs) is delivered to RID during the irrigation season (mid-March through October 20th). This canal also supplies water to the Roza Power Plant located about 10 miles downstream from the dam. The Roza Canal headworks are located on the right abutment of the diversion dam, and consist of a concrete structure with a trashrack located at the inlet end protecting the revolving fish screens in the transition section. A radial gate at the outlet end controls discharges into the canal. The main fish ladder is a concrete structure in the left abutment. An auxiliary ladder is located in the right abutment and is connected by a gallery to the main fish ladder. Operation of the fish ladder, including the auxiliary water supply, requires a minimum flow of about 120 cfs to remain within criteria.

The Roza screening facility (located in the transition section) in the forebay pool above the Roza Diversion Dam is designed to prevent fish from entering the Roza Canal, which carries up to

2,200 cfs year around for irrigation and power generation. Maximum diversion into the canal occurs from May through September in most years. The canal is usually empty for several weeks during late October and/or November for canal and fish passage maintenance. The Roza fish screen structure is the largest fish passage structure in the Yakima basin, containing 27 drum screens, each 17 feet in diameter and 12 feet long. Five 30-inch-diameter pipes with capacities of 50 cfs each are provided to return the fish that encounter the screens to the river. Operation of the fish screen facility requires a flow of 100 to 250 cfs to meet criteria with flow being pumped back to the canal. The primary components of the Roza screening facility include the trashrack, drum screens, fish bypass structure, fish return pipe, juvenile evaluation facility, and the canal juvenile pumpback system, including the secondary screening system.

The two 110 foot Roza Diversion Dam roller gates were designed to allow either gate to be operated independently, either manually, or by float controlled automation, to maintain the water surface in the reservoir at elevation 1220.60 (+4", -2") with normal flow in the river, and at elevation 1220.60 (+10-5/8", -2") for flood discharges. Excess water over the requirement for canal diversion is passed through the roller gates. Because a roller gate can be lowered approximately 5 feet past the closed position (tucked) to spill water over the top of the gate, the lower seal, instead of being mounted to bear down onto the gate sill, is mounted on the upstream face of the sector or lip and contacts an embedded steel beam, which is mounted on the downstream face of the gate sill. When the gate is in the closed position it is called "on seal." If it is lowered below this position it is said to be "tucked." (Note: the gate seal position is set to account for deflection of the gate caused by hydrostatic loading.) Seal damage can occur if the gate is operated in the dry. The bottom seal will not properly engage without full pressure on it, and it will be damaged if the gate is moved without the reservoir being full. Both roller gates should be opened to drain the reservoir, and if a gate is on seal it should be opened first. When refilling the reservoir the gates may not be closed tight against the seal until the reservoir is full. The submerged position (tucked) of the gates is used in clearing the surface of the reservoir of ice and debris.

During normal operations on float control, 1 gate will handle discharges from zero (80+ cfs leakage) to 7,500 cfs, with gate opening from seal to 3.0 feet, and a variation of reservoir water surface from elevation 1220.43 to 1220.65 feet. As discharge exceeds 7,500 cfs float control automation begins to become unstable and manual operation is used as needed. Normally, the left roller gate is used to bypass flows at Roza Dam. Having flows pass through the left gate reduces the sediment buildup on the upstream side of the left bank fish passage and also reduces the possibility of silting in, and becoming inoperable. Periodically, the right roller gate should be operated, allowing flows to pass for a short period of time, to wash away accumulated sediment from in front of the auxiliary ladder located in the right abutment. The 2 Roza Dam roller gates together will handle discharges up to 52,000 cfs, with both gates open to 12.5 feet. The reservoir water surface will range from elevation 1220.65 to 1221.48 feet. When the river system is on storage control the float control automation, in trying to hold reservoir level, may set up an hourly (or more) cycling effect of +/- 80 cfs, that carries all the way down the Yakima River to PARW gaging station, creating one source of variation to PARW target flows.

The Roza Diversion Dam is operated at full pool normally 11 months of the year, including the winter months of December, January, and February. Due to the power water diversion in the canal, the fish screens remain set throughout the winter (year-round) and icing problems may occur damaging the metal screens structures or freezing up the screens, and damming off the canal flow. When the river is ice bound, or the reservoir surface is vulnerable to freezing over or has frozen solid, the roller gates may be tucked (allowing ice to pass over the roller gates) to clear the surface of the reservoir of ice, or opened to keep a flowing channel through the reservoir area. This is done to prevent damage to the fish screens, roller gates, and the diversion structure. In an extreme cold weather period the river system develops thick ice. To prevent ice jamming under the roller gates and floating them out of position or structurally damaging them, Reclamation fully raises the gates, allowing all flow to pass, and drawing down the pool to protect the structure. In addition, the power plant operation is suspended due to the ice problems. Ice Watch (CC25) is conducted during the colder, freezing periods of winter weather (typically December, January, and February).

A drawdown of Roza Diversion Dam pool for maintenance (canal and fish screens) has historically created issues for the biologists. These include: stranding of fish, ramping rates, minimum pool, sediment movement, and functionality of fish passage. Whenever pool drawdown is necessary, river flows will be affected, and gate operations must be accomplished in an environmentally sound manner, with advance consultation between Yakima River operations and the Upper Columbia Area Office Biologist to avoid damage to fisheries. Drawdown of the Roza Dam Pool is held to approximately 1 to 6 inches per hour (depending upon pool elevation and current conditions) which allows time for fish movement out of the shallow areas of the pool, reduces stranding, and minimizes sediment movement from the dewatered side slopes of the pool. For screen maintenance, the pool elevation is drawn below the sill at the bottom of the transition section trashrack intake to the fish screens at elevation 1209.75 feet. A target range pool elevation between 1209.00 and 1208.50 feet allows work in the fish screen section and, at the same time, avoids scouring silt and associated downstream impacts. This pool elevation allows for the fish ladder to be adjusted for usable fish passage through the secondary low pool exit. The downstream river has a general ramping guideline of 2 inches per hour, whenever operationally possible.

A concrete transition section connects the fish screen structure to the headworks gate structure which controls deliveries to Roza Canal with a 28 foot by 15 foot radial gate. To maintain canal integrity, canal flow should not increase or decrease more than 100 cfs per hour, except in an extreme emergency. When starting the juvenile pumpback pumps, the canal radial gate should be adjusted to lower or raise the canal flow approximately 50 cfs per pump, matching the number of pumps to be started or stopped. Power flow reductions in Roza Canal Diversion may cause a 2-3 hour “hole” in Yakima River flows below the Roza power wasteway as observed at the Parker gage. This is due to travel time of flow in the canal, which requires 3 hours to the end of the power wasteway at Yakima River at Terrace Heights (YRTW) versus approximately 6 hours via the river from Roza Dam.

Power water for electric generation at Roza Power Plant is subordinated to fishery flows in the Yakima River below Roza Diversion Dam (RBDW). Reclamation maintains an informal agreement, in consultation with SOAC, BPA, and others, to subordinate power generation to maintain a 400 cfs minimum in the river. Reclamation supports a 300 cfs minimum target (with no power generation) with natural flow water available in river system, but will not provide storage to maintain the 300 cfs minimum. During water year 2000, from November 8, 1999 through March 15, 2000, power was subordinated through negotiations with BPA, to a minimum flow of 600 cfs. The power subordination target returned to the 400 cfs minimum as of March 16, 2000, that year.

Yakima Project operations monitors and coordinates closely with Roza Power Plant operators to maintain appropriate flows for instream target minimums; irrigation and hydroelectric power diversions; and to accomplish a variety of operational needs, including power subordination, fisheries, flood control, recreation, and maintenance. In the past, Reclamation has provided river flow modifications (reductions) to support maintenance on the diversion dam and fish passage structures. Instream target flows and ramping rates below Roza Diversion Dam are monitored at the Yakima River below Roza Dam gaging station (RBDW).

Yakima-Tieton Diversion Dam -

Yakima-Tieton Diversion Dam (Tieton RM 14.1) is a 110-foot-wide concrete fixed crest weir (elevation 2301.6 ft.) with fish passage located on the right abutment, located on the Tieton River about 16 miles southwest of Naches, Washington. This irrigation diversion check structure (hydraulic height 3.0 ft.) provides water diversion for the Yakima-Tieton Irrigation District (YTID) during the irrigation season (mid-March through mid-October). The diversion structure has a designed diversion capacity of 320 cfs, but in reality is capable of passing up to 350 cfs. The dam as originally built had an overall height of 5 feet. In 1990, the diversion structure was modified for recreational rafting passage with the original downstream timber apron of the structure having been replaced with a concrete ramp. The ramp is 3 feet high and extends approximately 20 feet to transition into the downstream riprap. The current vertical drop from the dam crest to the top of the ramp is 2 feet, enabling most rafters to float over the diversion dam with of safety.

In 1990, the existing sluiceway, located on the right (south) side of the dam, was also modified to include a fish ladder to aid passage under low flow conditions. In 1996, a new flat plate fish screen was installed, 1,000 feet down the YTID main canal (TIEW) with a fish return pipe to the right side of the Tieton River. As all fish protection facilities and the main canal are located on the right side of the river (no bridge access), maintenance work requires a river ford access to the canal or fish screens at Yakima-Tieton Diversion Dam and possible corresponding outflow reductions at Tieton Dam (Rimrock Lake). Operations monitors and coordinates closely with YTID to maintain appropriate flows for irrigation diversions and to accomplish a variety of operational needs, including fisheries, flood control, recreation, and maintenance to structures.

Ramping rates below Tieton Diversion Dam are monitored at the Tieton River below canal headworks gaging station (TICW).

Wapatox Diversion Dam -

Wapatox Diversion Dam (Naches RM 17.1) is a 210-foot- wide concrete fixed crest weir (elevation 1585.0 ft.) with removable flashboard capability, located on the Naches River about 4.2 miles west of Naches, Washington. This irrigation and hydroelectric power diversion check structure (hydraulic height 6.0 ft.) is owned, operated, and maintained by PacifiCorp, and diverts up to 500 cfs to the Wapatox Power Canal (PacifiCorp, Scottish Power) and Wapatox Irrigation during the irrigation season (mid-March through mid-October). This diversion has a year-round natural flow right of 300 to 450 cfs, and diversion from the river is allowed up to 450 cfs, so long as the flow is naturally available and the rights of senior diverters and users, including flows to protect anadromous fish life, are satisfied. Reclamation is not obligated to provide storage flows at any time. During the non-irrigation season (winter) the power diversion water is informally subordinated to maintain a 125 cfs instream flow in the Naches River below the Tieton River near Naches, Washington (NACW). This structure has a passage with 125 cfs flow on the left abutment, which serves as a fish ladder, with 3 pools of approximately 2 feet per jump.

Operations monitors and coordinates closely with PacifiCorp to maintain appropriate flows for instream target minimums; irrigation and hydroelectric power diversions; and to accomplish a variety of operational needs including power subordination, fisheries, flood control, recreation, and maintenance. In the past, Reclamation has provided river flow modifications (reductions) in an attempt to support maintenance and flashboard installation on the diversion dam. Instream target flows and ramping rates below Wapatox Diversion Dam are monitored at the Naches River below Tieton River near Naches, Washington gaging station (NACW).

Naches-Cowiche Diversion Dam -

Naches-Cowiche Diversion Dam (Naches RM 3.6) is a concrete gravity ogee-weir, with the crest (elevation 1190.+) having removable flashboard capability, and with fish passage located on the left abutment. An irrigation diversion check structure (hydraulic height 8.0 ft.), owned jointly by Naches-Cowiche Ditch Company and the City of Yakima, is operated and maintained by the City. The diversion provides separate water diversion for the Naches-Cowiche Ditch Company and the City of Yakima Irrigation (old City Ditch) on the right bank during the irrigation season (mid-March through mid-October). The City provides all operation needs at the site, based upon the design operation criteria. In the past, Reclamation has provided river flow modifications in an attempt to support maintenance and flashboard installation. There is no minimum flow requirement downstream of this structure.

Wapato Diversion Dam -

Wapato Diversion Dam (Yakima RM 106.6) consists of two concrete weir structures. The west branch crest (elevation 935.6 ft) and the east branch crest (elevation 936.00 ft) are about 14 feet high and located on 2 branches of the Yakima River, about 1 mile north of Parker, Washington. Just upstream from the two structures, the Yakima River separates to form an east branch and a west branch with an island between the two branches. The two structures that comprise Wapato Diversion Dam raise the level of the river to divert water to the Wapato Irrigation Project (WIP) main canal. The headworks for the main canal is on the right abutment of the west branch structure and provides diversion of up to 2,200 cfs to WIP during the irrigation season (mid-March through October). The diversion headworks and fish passages facilities are owned by the United States, with WIP-BIA operating and maintaining the dam and headworks, and Reclamation operating and maintaining the fish passages facilities.

Adult fish passage at the dam is provided by three vertical slot fish ladders. The east branch dam has fish ladders located in the center and at the right bank against the island. The west branch of the dam has a center fish ladder of the same design as the east branch center ladder. Each fish ladder is designed to operate through a broad range of river flows, with attraction water provided for each ladder. Approximately 425 cfs is needed to operate the 3 ladders to within criteria when the low flow entrances are being used. At higher river flows, the ladders use the high flow entrance, and the total water used by the ladders would be approximately 825 cfs. Operation of the fish screens bypass, whenever diversions are made to WIP main canal, uses flows of 120 to 180 cfs to remain in criteria.

For operation and maintenance of the west branch ladder, and to provide access to the ladders on the east branch diversion structure, a cable car and a cableway are provided from the right bank to the left bank (island). This cableway access provides for daily operations and light maintenance of the east branch dam and fish ladders, but heavy maintenance work requires access via a river ford downstream of the west branch diversion dam and possibly corresponding outflow reductions at reservoirs to support the fording operation. WIP has bulldozed gravel dikes into the east branch of the Yakima River, at the upstream tip of the island, to enhance flow to the west branch diversion. In the past, Reclamation has attempted to provide river flow modifications to support maintenance and dike installation.

Operations monitors and coordinates closely with WIP to maintain appropriate flows for irrigation diversions and to accomplish operational needs for fisheries and maintenance to structures. WIP attempts to follow ramping criteria for the river when making changes in canal diversion, using the target flows and ramping rates for Yakima River near Parker (PARW) as a guide. There is no minimum flow requirement downstream of this structure.

Sunnyside Diversion Dam -

Sunnyside Diversion Dam (Yakima RM 103.0) is a 500-foot-wide concrete ogee-weir (elevation 899.4 ft.) with a right embankment wing, and fish ladders located on the right and left abutments, plus a center fish ladder midway across the crest of the dam. This irrigation diversion check structure (hydraulic height 6.0 ft.) provides water diversion (maximum 1,320 cfs) for the Sunnyside Canal with headworks located on the left bank. Canal flow varies from 600 to 1,300 cfs during the irrigation season (mid-March through October 20). The diversion dam is owned by the United States, and is operated and maintained by Sunnyside Valley Irrigation District (SVID). Fish passage facilities are operated and maintained by Reclamation. Operations monitors and coordinates closely with SVID to maintain appropriate flows for irrigation diversions and to accomplish a variety of operational needs, including fisheries, flood control, recreation, and maintenance to structures. Instream target flows and ramping rates below Sunnyside Diversion Dam are monitored at the Yakima River near Parker, Washington gaging station (PARW).

Adult fish passage at the dam is provided by three vertical slot fish ladders. Each fish ladder is designed to operate through a range of river flows from 200 to 12,000 cfs, with attraction water provided for each ladder. Approximately 340 to 400 cfs is needed to operate the 3 ladders to criteria when the low flow entrances are being used. Under present operations the minimum YRBWEP Title XII flow past the dam is 300 cfs (or 65% of 300 cfs < 24 hours), with ladder operations modified to operate in these low flow conditions. At high river flows, when the high flow ladder entrances would be used, a flow of 600 to 660 cfs is required. Operation of the fish screens bypass during diversions to the canal uses flows of 80 to 120 cfs to remain in criteria. Pumpback capability at the screen site returns from 40 to 80 cfs to the canal and only 20 to 40 cfs is bypassed to the river below the PARW gage.

During modification of the fish passage facilities, an agreement was made to protect the ability of SVID to withdraw water at Sunnyside Diversion Dam. If the target flow at PARW is 400 or 300 cfs, and the left, center, and right ladders are operating in criteria, 340 to 400 cfs minimum is passing through the ladders. Thus, if the SVID is taking 1,200 cfs, 1,600 cfs must be delivered to the diversion dam, plus an additional amount to cover daily fluctuations. If any less is delivered, the level of the pool above the crest of the dam drops. When this happens, head pressure is lost across the canal head gates, and the canal flows drop. The head gates are raised to compensate, and soon the system is in the critical situation where the canal head gates are fully open, but the level of the forebay pool is too low to deliver the required water to the district. As soon as 30 cfs is lost in the canal, SVID irrigators that receive their water from turnouts set high in the canal are no longer served. Then, any water delivered to the diversion dam to compensate must first fill the lake, extending the service outage time to SVID irrigators.

Sunnyside Low Flow Automation (SLFA) was designed and built as a means of protecting both the irrigation and fishery interests. During periods of limited flows at PARW (400 cfs or less), the SLFA will attempt to maintain the SVID diversion dam forebay level and provide the best fish passage for the remaining flows at PARW by adjusting the gates on the three fish ladders. As flows drop to the first point of inability (400 cfs) to meet full irrigation deliveries and maintain the forebay level of the pool behind the dam, the left and right ladder's attraction gates are closed. At 300 cfs the left and right entrance gates are closed, effectively shutting down these ladders. At this point, most of the river channel flow is in the center of the stream, and fish ladder functionality is concentrated to the center ladder. If the flows drop another 100 cfs (to 200 cfs), the center ladder attraction gates are opened and closed as necessary in an attempt to hold the forebay pool level as close as possible to the crest level of the diversion dam. Before this, operations will have seen the shortage in river flows, and will have started compensating by releasing water out of a reservoir. However, there may be short periods of time where flows at PARW will drop below the target. When flows start to increase, the SLFA will automatically reverse this process and attempt to return the ladders to full criteria. Note: if the YRBWEP target is 300 cfs the left and right bank ladders will operate the entire July through October period with the attraction gates closed.

The Sunnyside fish screen pumpback pumps are known to have shutdown in the past, creating a quick 40/80 cfs loss at PARW and possibly starting the above described low flow sequence of events. This also adversely affects the SVID irrigators that are supplied by turnouts set high in the canal. This loss of water could be taken out of the system by motorization and utilizing local control of the fish water bypass gates, thus having the bypass gates temporarily cut back flow to offset pump shutdown and still maintain a steady flow in the Sunnyside Canal. At the same time, status warning alarms would provide a call for pump maintenance. This process drives the sweep velocities of the fish screens out of criteria for a short period of time until the pumps are repaired, but stabilizes the river flows below the diversion dam. This modification of flow procedures was presented to SOAC and was given approval and will be implemented when labor and budgets allow.

The Sunnyside Diversion forebay pool is split into two sections by an island and two riffles that are increasing in size yearly. The right side pool/channel is the dominant flow, with water passing over the dam crest between the center and right ladder, while the left side pool (SVID diversion side) is drawn below the dam crest between the left and center ladder. This causes problems in meeting deliveries to SVID due to head loss, and with the head gate fully open, an inability to compensate for the situation. This problem will most likely occur when PARW flows drop below 600 cfs. In this situation, SVID may need to remove material from the forebay and riffles to keep the diversion dam structure functional in low flow conditions after the storage control date.

Prosser Diversion Dam -

Prosser Diversion Dam (Yakima RM 47.1) is a concrete weir structure about 9 feet high and 661 feet long with a crest elevation of 633.5 feet. This irrigation and hydroelectric power diversion check structure (hydraulic height 7.0 ft.) is owned by the United States, operated and maintained by Reclamation, and provides water diversion of up to 1,500 cfs into the Chandler Canal for irrigation and power production at the Chandler Power and Pumping Plant at the end of the 11 mile canal. The Chandler Power and Pumping Plant pumps water (up to 334 cfs) across the Yakima River to the Kennewick Canal, for delivery to the Kennewick Irrigation District during the irrigation season (mid-March through mid-October). The diversion headworks is located on the left abutment of the dam; housing three 16 by 7.75 foot radial gates to control flow to the canal. The canal is usually empty for several weeks during late October and/or November for canal and fish passage maintenance.

Fish passage facilities at the dam include fish ladders located on the right and left banks, plus a centrally located ladder and the Chandler screen facility located downstream of the dam. Operation of the 3 fish ladders at lower river flows requires flows of about 350 cfs. At higher river flows, the total water use by the ladders, including attraction water, is about 450 cfs.

Due to its location in the river system, large amounts of debris accumulate at the dam. Debris removal is a major issue for operation of the Prosser facilities because; 1) passage becomes ineffective due to the trashracks and water intakes becoming clogged; 2) debris, including large trees, is swept over the dam crest and lodges at the toe of the dam streambed creating bays and obstacles which hinder the upstream movement of fish through the ladders; and 3) debris facilitates damage to the diversion dam structure. Depending on the volume of debris moved in the river system, the debris could require yearly attention and removal during a low flow period in the river.

The Chandler screen facility is located in the Chandler Canal approximately 1 mile downstream of the Prosser Diversion Dam. The primary components of the Chandler screen facility include the drum screens, the pumpback-bypass facility, and the juvenile evaluation facility. The screening facility houses twenty-four 13.5-foot-diameter by 12-foot-long rotating drum screens. Fish enter the bypass system through 3 entrances located at 100-foot intervals across the screening structure. These fish are conveyed to the pumpback-bypass facility through three 42-inch-diameter pipes. Of the total 132 cfs of bypass flow, up to 105 cfs can be returned to the canal via the pumpback-bypass facility. Two traveling screens protect fish from the pumpback bays. Bypass flows of 27 to 32 cfs are delivered from the pumpback facility to the juvenile evaluation facility. At the facility, fish can be diverted directly back to the river or to a trap where they can be sampled and inspected. Annual maintenance usually requires the screen facility to be dewatered (canal shutdown) for 2 to 3 weeks for work completion. The dewatering process places fish in the canal above the screen at risk. Coordination with WDFW occurs so that the canal head gates are shutdown in a manner that allows fish to return to the river prior to complete closure of the head gates. The YN fish acclimation ponds located in the immediate area rely on the Chandler Canal screen fish bypass water flows for refreshing the ponds. When the canal is shutdown, coordination with the YN is necessary to ensure alternate water sources for the acclimation ponds.

Due to the location in the river system, deposition of large amounts of silt accumulates at the fish screen facilities as the water velocity in the canal is slowed to the 0.5 cfs velocity required through the screen. During routine maintenance shutdown, removal of accumulated silt and dumping of the material at disposal sites is completed as necessary. Due to the power water diversion in the canal the fish screens remain set throughout the winter (year-round) and icing problems may occur damaging the screens structures or freezing up the screens, damming off the canal flow. When the river is ice bound or the canal is capable of freezing, and in order to prevent damage to the fish screens facilities and canal structure, power plant operation may be suspended and the canal shutdown until the ice problems diminish. Ice Watch (CC25) is conducted during the colder, freezing periods of winter weather (typically December, January, and February).

Reclamation subordinates power production of Chandler Power Plant to various flows passing over Prosser Diversion Dam throughout the year. In the spring, the subordination target is 1,000 cfs over Prosser Dam through the end of June. During the remainder of the irrigation season, the subordination target is 450 cfs or the YRBWEP target flow, whichever is higher. The agreed subordination target is for 450 cfs through the non-irrigation season, but for the past 2 years all subordination target flows have been annually reviewed and reestablished.

Operations monitors and coordinates closely with Chandler Power Plant operators to maintain appropriate flows for instream target minimums; irrigation and hydroelectric power diversions; and to accomplish a variety of operational needs, including power subordination, fisheries, flood control, recreation, and maintenance. In the past, Reclamation has provided river flow stabilization or modifications (reductions) in an attempt to support downstream river flow studies and maintenance on the diversion dam and fish passage structures. YRBWEP target flows, instream target flows, and ramping rates below Prosser Diversion Dam are monitored at the Yakima River at Prosser, Washington gaging station (YRPW).

Wanawish/Horn Rapids Diversion Dam -

Wanawish Diversion Dam (Yakima RM 18.0) is a 523-foot-wide concrete fixed crest weir (elevation 414.3 ft.), with fish ladders located on the right and left abutments, plus 3 fish passage notches evenly distributed across the crest of the dam. This irrigation diversion check structure (hydraulic height 3.0 ft.) provides water diversion for the Columbia Irrigation District (CID) on the right bank, and diversion for the Richland Canal (Barker Ranch Canal) on the left bank. The diversion dam is owned, operated and maintained by CID, and the district operates the site, based upon the design operation criteria for Horn Rapids right ladder and the irrigation demands of the district. There is no minimum flow requirement downstream of this structure. From mid-March through October, water is diverted for irrigation by both entities, and from November through March, the Richland Canal at times diverts water for wetland enhancement.

5.5 Operations for System Maintenance

Routine maintenance of the facilities occurs throughout the year on the Yakima Project. This routine maintenance falls into two broad categories; maintenance of the storage dams and canals; and maintenance of the fish protection facilities. Reclamation maintains the storage dams, two diversion dams, and the fish protection facilities. Maintenance at these facilities is conducted according to the Standard Operating Procedures (SOP) for each facility. There are specific SOPs, described in separate manuals, for each site: Keechelus Dam, Kachess Dam, Cle Elum Dam, Tieton Dam/Rimrock Lake, Bumping Lake Dam, Clear Creek Dam, Easton Diversion Dam, Roza Diversion Dam, Sunnyside Diversion Dam, Prosser Diversion Dam, and Tieton Diversion Dam. Copies of these manuals are kept at the Yakima Project Office.

5.5.1 Storage Dams and Diversion Dams (CC27)

Inspections of the dams, spillways, outlet works, and other facilities are followed by required maintenance and repairs, if needed. The requirement for instream flows downstream of the dams continues during all inspection, maintenance, and repair activities. Inspections and maintenance crews must consult and coordinate with the project's hydrology operations branch and Reclamation environmental programs staff prior to implementing required activities in order to minimize adverse impacts to storage, flood control, irrigation diversion, fishery, and natural resources. The instream flow requirements are coordinated with the flow requirements necessary to perform the maintenance and repair activities and to determine which month of the operating year is the most suitable time for the work. Most maintenance and repair activities are scheduled in advance (obviously an emergency is just that). Advance planning, taking into consideration storage, fishery flows, flood control, conditions of water, etc., is required to create a non-disrupted flow regime during maintenance and repair activities. A 15-month lead time is within reason, and even then, the activities may be delayed due to changing basin conditions. The flip side to advanced planning is the need to have flexibility in scheduling and manpower, so "windows of opportunity" may be used to do the activity earlier rather than later when scheduled.

5.5.2 Fish Protection Facilities (CC28)

Fish passage and protection facilities have been constructed throughout the Yakima basin. Fish ladders provide passage around dams for adult fish returning to their upstream spawning beds. Efficient fishways are vital to avoid injuries or delays in this migration. Most of the new ladders have a vertical slot design with low and high flow entrances. A jet of water flowing from the ladder attracts fish to the entrance. The fish then swim through the slots from pool to pool, resting in each before swimming to the next.

Fish screens keep juvenile fish from swimming into canals where they become trapped and may die. Most Yakima fish screens have rotating drums covered with wire mesh. These are submerged into the canal water about 80 percent of the drum diameter. The screen structure is angled to the direction of the canal flow so that the young fish are directed into a bypass pipe and back into the river.

Both screens and ladders require considerable maintenance. Reclamation is responsible for operation and maintenance of many of the screens and ladders throughout the basin. General maintenance consists of daily inspections, annual inspections, and scheduled 4-year reviews of

O&M inspections. Maintenance or repair activities are based on the inspection findings and scheduled maintenance.

Daily Inspections -

During operating periods, Reclamation employees or contractors check screens and ladders for vandalism and to ensure that the facilities are operating properly. These daily checks include; 1) determining that the screens are 80 percent submerged, 2) adjusting fish bypass flows to ensure that they are within operating criteria, 3) assuring that the ladders meet attraction flow criteria, and 4) removing debris to prevent equipment failure or impairment.

Annual Inspections -

Every year, the fish screens must be inspected and any required maintenance conducted. Most annual maintenance is accomplished during the non-irrigation season. Usually the screen site must be dewatered and the larger sites, such as Roza and Chandler, require about 2 weeks for work completion. The dewatering process places fish at risk in areas where the water pools in depressions rather than draining directly to the river. Sites where fish can be stranded include Chandler, Sunnyside, and Roza Diversion Dams. These sites are discussed in some detail in the "effects" section. Fish screen maintenance activities are coordinated with the WDFW personnel. For example, Reclamation inspects screens and bypasses and informs WDFW of potential fish issues at each site. Upon completion of annual maintenance and screen repairs WDFW re-inspects each site to ensure that the facilities are operating to meet the fish criteria for which the facilities were designed. In addition, coordination occurs with the irrigation districts so that the canal head gates are shutdown in a manner that allows fish to return to the river prior to complete closure of the head gates (WDFW, 1996).

Once the site is dewatered, screens, bays, and bypasses are inspected during the annual maintenance routine. The maintenance focuses on seal replacement, drum screen repairs, and a thorough bypass pipe inspection. Deposition of silt occurs at the screen facilities as the water velocity in the canal is slowed to the 0.5 cfs velocity required through the screen. Routine maintenance also includes the removal of accumulated silt as necessary and transport of the material to approved disposal sites. The screens and frames are washed down.

The screens are re-installed when the maintenance is completed and WDFW then inspects the screens to verify Reclamation's work and to ensure that the screens are fish tight. At these onsite inspections, coordination and information exchange occurs between Reclamation staff and WDFW staff. Repairs, general maintenance, and any unusual findings are discussed.

Four-Year Inspections -

Every 4 years, a review of O&M activities occurs at each of the fish protections facilities (e.g., about 20 sites per year are reviewed). This review includes Reclamation staff from the Yakima Field Office and the Boise Regional Office. Results are reported to the Denver Technical Service Center. Fish passage, safety, and major structural issues are examined to ensure that O&M activities are conducted efficiently and effectively.

6.0 EFFECTS OF SYSTEM OPERATIONS ON:

6.1 WATER

6.1.1 Quality

6.1.1.1 Introduction

The U.S. Environmental Protection Agency (EPA) has determined that agricultural runoff is the major source of water quality degradation in Washington State's rivers and streams, with hydrologic habitat modification considered to be the second most important cause of water quality impairment in the State (EPA, 1998).

Normal and emergency Yakima Project operations and maintenance activities alter flow volume and water levels, affect normal temperature regimes, and periodically increase suspended sediment and turbidity outside the range of State water quality criteria. Large volumes of polluted agricultural return water from the Yakima Project add a variety of contaminants to the river, including nutrients, bacteria, pesticides, and sediment. Agricultural return flows, an indirect effect of the Yakima Project, are responsible for many of the “water quality impaired” listings on the 1998 303(d) list. Recent improvements in farming practices have improved water quality by reducing sediment entering the river. (See table 6-1. for improvements on Roza-Sunnyside Board of Joint Control.)

Table 6-1. -Summary of RSBOJC Water Quality Data
1997-2001

90th% Turbidity (NTU)

	WDOE	RSBOJC Data					
	1994 Irr (June-Oct)	1995 Irr (March-Oct)	1997 Irr (June-Oct)	1998 Irr (April-Oct)	1999 Irr (April-Oct)	2000 Irr (April-Oct)	2001 Irr (April-Oct)
Granger Drain	195	345	298	125	136	42	46
Sulphur Creek	29	70	81	60	51	18	15
Spring Creek	17	106	49	49	45	25	14
Snipes Creek	15	64	21	27	20	15	9

Median Total Suspended Solids Loading (tons/day)

	WDOE	RSBOJC Data					
	1994 Irr (June-Oct)	1995 Irr (March-Oct)	1997 Irr (June-Oct)	1998 Irr (April-Oct)	1999 Irr (April-Oct)	2000 Irr (April-Oct)	2001 Irr (April-Oct)
Granger Drain	16	72	100.2	35.2	43.1	15.5	4.8
Sulphur Creek	8	87	152	86.3	108.3	44	3.7
Spring Creek	1	15	13.3	6.8	9.3	5.1	2.7
Snipes Creed	0.004		4	4.3	1.9	1.1	0.03

90th% Total Suspended Solids (mg/L)

	WDOE	RSBOJC Data					
	1994 Irr (June-Oct)	1995 Irr (March-Oct)	1997 Irr (June-Oct)	1998 Irr (April-Oct)	1999 Irr (April-Oct)	2000 Irr (April-Oct)	2001 Irr (April-Oct)
Granger Drain	408	771	894	432	543	125	100
Sulphur Creek	57	213	307	197	159	57	33
Spring Creek	45	295	165	119	132	85	38
Snipes Creed	10	224	53	87	47	37	20

Decades of water quality studies have been conducted within the Yakima basin focusing on many of the impairments that have been identified within the river system. Several of these studies have examined specific cause and effect in both a spatial and temporal view while others take a more generalized view, identifying water quality problems without fully quantifying pollutant loads or qualifying sources. It has been shown that in several circumstances Yakima Project operations, including water storage and distribution, the agricultural return flows used to satisfy total water supply available (TWSA) and the return flows from various Yakima Project Division operations, have contributed to impairment of water quality in the Yakima River. A direct correlation between some of the identified impairments within the system and the Yakima Project operation remain unquantified and under-defined; however, there are intuitive connections that can be drawn. The Yakima River is a heavily managed system and, as such, that management must be examined as a contributing factor to any known impairment within its reach. This section will identify several of the known impairments to water quality within the basin.

Effects of Normal Yakima Project Operations -

The mission of the Yakima Project operations has primarily been to supply water for irrigation in the Yakima basin. This activity often results in low water levels in the lower main stem of the Yakima River in the summer and fall and abnormally high flows in reaches of the upper main stem. Models and studies have shown that low water levels and the associated reduction in width-depth ratios can accelerate the heating of waterbodies, such as the Yakima River, which can in turn reduce the amount of available dissolved oxygen (DO) to below optimal levels. Low flows combined with high nutrient loads, as found in the lower Yakima, also promote macrophyte and phytoplankton growth in the river, which can result in increased pH levels and wide swings in DO concentrations.

While sediment and bedload movement does naturally occur within a river system, normal operation and maintenance activities of the Yakima Project have altered the timing, volume, and magnitude of sediment movement in the river. Drain maintenance, including dredging and flushing, has also contributed sediment and associated pollutants to the Yakima River system.

In years that have normal or above normal water supplies, standard Yakima Project operation has been to provide water to all Yakima Project divisions and client districts based on contract laws and State water law the amount of water available in the system. Amounts delivered to divisions and districts have averaged approximately 90 percent of the contract entitlement. This volume is not necessarily based on the precise needs of the various irrigators and their crops, but rather on the legal requirements. Instantaneous demands by individual irrigation districts can result in excess water deliveries due to inefficiencies in their system. Operational or excess water delivered to the various project divisions is returned to the river through operational spills or in drains at various locations within the division's district. During normal water years, especially during wet, cool weather, greater operational spill tends to occur in wasteways and agricultural drains.

During a normal water year with near full water entitlements delivered to growers, water from fields and drains tend to transport a greater pollutant load than during those years with less than a normal water supply. A positive correlation was shown to exist between the amount of water delivered to the districts and return flows carrying high loads of sediment and associated contaminants. In 1994, a low water year, 3 of the 4 major agricultural drains in the lower Yakima total maximum daily load (TMDL) study carried less flow volume, less sediment load, and maintained lower turbidity (lower concentration) than during the normal water year of 1995 (Joy and Patterson, 1997). During low water years greater care is given to how irrigation water is managed on-farm, which has resulted in more efficient use and less tailwater runoff.

Subsequent to the 1994-95 Department of Ecology (WDOE) study, marked changes have been seen in these same four drains in the lower Yakima basin. Dramatic improvements have been realized in sediment reduction in the lower basin since the Roza and Sunnyside Divisions began implementing a water quality program in 1997. Further reductions are expected within these divisions' boundaries and it is anticipated that they will meet sediment reduction targets set by the Lower Yakima Sediment and DDT TMDL and the fecal coliform bacteria (FC) reduction targets set by the Granger Drain FC TMDL.

Effects of Agricultural Return Water -

In the lower Yakima River, irrigation return flows and operational spills from drains and tributaries contribute up to 80 percent or more of the total flow in the main stem. As runoff from irrigated agricultural fields re-enters the Yakima River numerous water quality parameters are significantly altered. Agricultural surface drains can contribute the following to the Yakima River and its tributaries: increases in suspended sediment, turbidity, FC, pesticides, heat, and nutrients. The addition of these pollutants also facilitates a reduction in DO and an increase in pH. Several of these pollutants have caused 303(d) listings in the Yakima River and its tributaries. The relationship between return flows and temperature has not been quantified and further study is needed. The impacts of these pollutants are discussed in more detail in the following sections.

Washington State Water Quality Regulations -

Section 90.48.080 of the Revised Code of Washington (1987) states that ". . . it shall be unlawful for any person to . . . discharge into any of the waters of this state, or to cause . . . to be . . . discharged into such waters any organic or inorganic matter that shall cause or tend to cause pollution of such waters . . ."

Additionally, the State's antidegradation policy (Washington Administrative Code [WAC] 173-201A-070, WAC, 1997) declares that "existing beneficial uses shall be maintained and protected." The antidegradation policy also states that whenever waters are of a higher quality than the criteria assigned for said waters, the existing water quality shall be protected and pollution of said waters which will reduce the existing quality shall not be allowed, "except where: (a) the public interest is served, (b) all activities which result in the pollution of waters from non-point sources shall be provided with, all known, available, and reasonable methods of prevention, control, and treatment, and (c) when the lowering of water quality in high quality waters is authorized, the lower water quality shall still be of high enough quality to fully support all existing beneficial uses."

Lastly, Washington State has specific water quality criteria (WAC 173-201A-030, 1997), determined by class of waterbody, that delineate standards for all significant pollutants. Water quality assessments are compared to these criteria in the following sections.

Characteristic Uses -

The waters most affected by Yakima Project operations are Classes AA, A, and B waters. Generally, headwater streams and the upper reaches of the Yakima and Naches Rivers are Class AA, while the middle and lower Yakima and Naches Rivers and their immediate tributaries are Class A. Sulphur Creek is the only Class B waterbody in the Yakima basin. According to WAC 173-201A-030, 1997, water quality for Class A fresh waters shall meet or exceed the requirements for all or substantially all of the following characteristic uses (also called "beneficial uses"). Characteristic uses for Class A waters shall include, but not be limited to, the following:

- Water supply (domestic, industrial, agricultural).
- Stock watering.
- Fish and shellfish.
- Salmonid migration, rearing, spawning, and harvesting.
- Other fish migration, rearing, spawning, and harvesting.
- Wildlife habitat.
- Recreation (primary contact recreation [e.g., swimming, diving or water-skiing], sport fishing, boating, and aesthetic enjoyment).
- Commerce and navigation.

Characteristic uses for Class B waters are similar to those for Class A, with these differences: (1) water quality must meet or exceed requirements for <u>most</u> (but not all) uses; (2) water supply includes only industrial and agricultural (not domestic) uses; (3) spawning for salmonids and harvesting of shellfish are not included; and (4) recreational use includes "<u>secondary</u> contact" (e.g., fishing or wading), but not "primary contact."

Characteristic uses that are impaired directly by Yakima Project operations (and indirect effects such as agricultural flows) include: (1) domestic water supply; (2) migration, rearing, and spawning of salmonids and other fish species; (3) wildlife habitat; and (4) recreation. Heavy sediment loads impair the health of aquatic biota as well as affecting domestic water supply. The introduction of toxic materials such as pesticides can make the water unfit for use as a domestic water supply and recreation, and it can affect aquatic biota. High water temperature and low DO levels may also harm aquatic biota. Low flows can reduce recreational opportunities and flow fluctuation, if not managed carefully, can cause stranding of aquatic biota.

6.1.1.2 Suspended Sediment and Turbidity

Sediment delivered to streams can greatly impair or eliminate habitat for aquatic life. Additionally, the transport and fate of many constituents, including nutrients, oxygen-demanding compounds, some pesticides, trace elements, and FC, are often associated with increases in suspended sediment concentration. In the lower Yakima basin increases in turbidity have been directly correlated with increases in suspended sediment concentration.

According to the WAC (Chapter 173-201A, WAC, 1997), turbidity in Class AA and A waterbodies shall not exceed 5 nephelometric turbidity units (NTU) over background when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU. For Class B waterbodies (e.g., Sulphur Creek), turbidity shall not exceed 10 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 20 percent increase in turbidity when the background turbidity is more than 50 NTU. Background conditions are defined in Washington as, ". . . the biological, chemical, and physical conditions of the water body, outside the area of influence of the discharge under consideration."

While the State of Washington has water quality standards for turbidity, none have been developed for total suspended solids (TSS). However, recent TMDL data indicated significant positive correlations between TSS and turbidity ($r^2 = 0.956$) during the 1995 irrigation season, allowing one to address both TSS and turbidity through the State's water quality criteria. Another significant correlation ($r^2 = 0.747$) was found during the 1995 season between TSS and total DDT (t-DDT= DDT+DDE+DDD) in the lower Yakima River, which suggests that most t-DDT (total DDT) may be transported by suspended sediment or TSS (Joy and Patterson, 1997). Because of these significant correlations the lower Yakima TMDL uses turbidity as a surrogate for both TSS and t-DDT.

From the lower Yakima TMDL study, a 90th percentile turbidity target of 25 NTU (25 NTU correlates to 56 mg/L TSS in the lower Yakima) for the tributaries and return drains was recommended by the WDOE to protect aquatic communities from TSS effects and to significantly reduce t-DDT loads. Modeling indicated that achieving a limit of 25 NTU at the mouths of the major agricultural drains in the lower Yakima River would bring the main stem into compliance with State turbidity criteria. However, further reductions will be necessary to reach Human Health Criteria for DDT. Meeting the 25 NTU target and main stem criteria will require the largest return drains to reduce TSS loads by 90 percent or more over their 1995 irrigation season levels, which were under conditions of normal water availability (Joy and Patterson, 1997).

During the 1987-91 North American Water Quality Assessment (NAWQA) study, the U.S. Geological Survey (USGS) determined that the major source of suspended sediment and turbidity in the Yakima River basin is agricultural activity. Significant contributions of suspended sediment to the main stem river during the irrigation season came from Wilson Creek, Moxee Drain, Granger Drain, Sulphur Creek, and South Drain in the lower Yakima basin. High rates of sediment transport to tributaries were generally associated with contaminated return flows from irrigated agriculture (Morace et al., 1999).

In 1994, one of the lowest water years on record, WDOE found that Sulphur, Spring, and Snipes Creeks had median turbidities below 25 NTU. In 1995, considered a "normal" water year, the median turbidities of Sulphur and Spring Creeks were above 25 NTU, while the 90th percentile turbidities for Sulphur, Spring, and Snipes Creeks exceeded 50 NTU (Joy and Patterson, 1997). Salmonid feeding and growth have been shown to be negatively affected at turbidities above 25 NTU.

As part of the formulation of the Lower Yakima River Suspended Sediment and DDT TMDL, WDOE calculated a TSS loading balance from data collected during the 1995 irrigation season. The cumulative negative impact of tributary and drain loading on reaches of the lower Yakima River was clearly seen. For example, in the later part of the irrigation season, the Moxee Drain TSS load (35 tons/day) exceeded the Naches River's load (27 tons/day), even though the average water volume of the Naches River was 14 times that of Moxee Drain. Averaged over the irrigation season, Granger Drain contributed 60 tons of suspended sediment per day. The average sediment load from Sulphur Creek was 110 tons/day, and Spring and Snipes Creeks combined sediment load averaged 46 tons/day. Ungaged tributaries and instream sources also accounted for substantial loads during the irrigation season (Joy and Patterson, 1997).

It should be emphasized that significant reductions in turbidity and sediment load in all of the targeted major agricultural return drains of the lower Yakima River have been realized since WDOE's 1997 assessment report. The Roza and Sunnyside Divisions have implemented a highly successful water quality improvement program, which is anticipated to meet the TMDL target of 25 NTU at the mouths of the major drains within their districts by the end of 2002. Continued implementation of the lower Yakima River sediment TMDL through on-farm and irrigation district improvements is expected to further reduce sediment transport and turbidity. As a corollary, this same effort is expected to also reduce contamination from organochlorine pesticides, FC, and sediment borne phosphorus.

In the upper Yakima basin, during the 1987-91 water years, the USGS found the median TSS concentrations of monthly main stem samples ranged from 3 mg/L in the Yakima River at Cle Elum to 17 mg/L in the Yakima River at Umtanum (below the contribution of TSS from Wilson Creek). In the lower Yakima basin, the median suspended sediment concentrations increased from 20 mg/L in the Yakima River at Union Gap to 28 mg/L in the Yakima River at Grandview and 25 mg/L in the Yakima River at Kiona (see table 6-2 for additional USGS TSS and turbidity findings). The suspended sediment concentration at Grandview reflects local runoff from several agriculturally affected drains, including Sulphur Creek, the basin's largest agricultural drain, in which TSS values ranged from 7 to 909 mg/L (Morace et al., 1999).

Table 6-2. –Streamflow, suspended sediment concentration, and turbidity in tributaries having predominantly agricultural sources of water, Yakima River Basin, Washington, July 26-29, 1988. After Morace et al., 1999. **[If more than one sample was collected at a site, the median concentration is shown here]**

Yakima River Mile	Site Name	Streamflow (cfs)	Suspended Sediment Concentration (mg/L)	Turbidity (NTUs)
147.0	Cherry Creek at Thrall	127	82	37
107.4	Wide Hollow Creek near mouth at Union Gap	26	8	2.7
107.3	Moxee Drain at Thorp Road near Union Gap	76	565	150
106.9	Ahtanum Creek at Union Gap	7	3	3.0
83.2	Sub-Drain Number 35 at Parton Road near Granger	34	7	8.0
82.8	Granger Drain at mouth near Granger	49	428	>100
61.0	Drainage Improvement District (DID) Number 3	26	356	>100
61.0	Sulphur Creek Wasteway near Sunnyside	159	113	- -
41.8	Spring Creek at mouth at Whitstran	24	138	33
41.0	Snipes Creek at mouth at Whitstran	24	136	>100
33.5	Corral Canyon Creek at mouth near Benton	16	27	3.6

WDOE ambient monitoring data collected at or just above the city of Yakima and at Benton City has shown regular excursions beyond State standards in recent years. It is expected that major recent reductions of sediment load in several of the lower Yakima basin return drains will result in improvement in lower Yakima main stem turbidity.

6.1.1.3 Abnormal Flows

A fundamental component of Yakima Project operations is reservoir storage and diversion of water from the main channels in the Yakima River system, often resulting in abnormal flow regimens, which can impair beneficial uses of the river.

Modeling has shown that reducing the water level in a river can cause it to be more prone to heating. Low flows can produce significantly increased surface area-to-volume ratios, which accelerate the rate of convective, conductive, and radiant heating. As temperature increases, oxygen-holding capacity of the water is decreased. Since low flows also promote the growth of aquatic plants (macrophyte and phytoplankton), the changes in stream chemistry (e.g., DO and pH) exerted by plant growth and respiration can further impair the health of the aquatic community.

Another effect of low flows is excessive sediment settling in different areas of the river system and storage of the sediment as bedload. River channels with reduced flow volume or velocity become accumulation sites for sediment delivered from the agricultural return drains. Sediment reduces higher quality salmon spawning areas, increases accumulation of toxic pollutants associated with the sediment, and encourages nuisance macrophyte growth. Stored sediment can be released only with bankfull flows or greater. The Yakima Project has generally reduced the height and the duration of these "flushing" flows in much of the river system.

6.1.1.4 Temperature

On Washington State's 1998 303(d) list of Impaired and Threatened Waterbodies, there are 15 listings for temperature in waters influenced by the Yakima Project (Ecology, 1998) (see table 6-3.).

Table 6-3.–1998 303(d) listings for temperature, in waterbodies affected by the Yakima Project (Ecology, 1998).

WRIA	Waterbody Name	Parameter	Township	Range	Section	New ID #	Old ID#
37	GRANGER DRAIN	Temperature	10N	21E	22	KO70CH	WA-37-1024
37	MOXEE (BIRCHFIELD) DRAIN	Temperature	13N	19E	16	OI57XE	WA-37-1048
37	SNIPES CREEK	Temperature	09N	25E	27	SL56UX	WA-37-1012
37	SPRING CREEK	Temperature	12N	19E	05	NO-ID	WA-37-2105
37	SPRING CREEK	Temperature	12N	19E	08	NO-ID	WA-37-2105
37	SULPHUR CREEK WASTEWAY	Temperature	09N	22E	24	YT62AF	WA-37-1030
37	YAKIMA RIVER	Temperature	08N	24E	01	EB21AR	WA-37-1010
37	YAKIMA RIVER	Temperature	09N	26E	13	EB21AR	WA-37-1010
37	YAKIMA RIVER	Temperature	09N	27E	19	EB21AR	WA-37-1010
39	CHERRY CREEK	Temperature	17N	19E	31	FT68CI	WA-39-1032
39	COOKE CREEK	Temperature	19N	20E	19	SZ58XV	WA-39-1034
39	WILSON CREEK	Temperature	17N	19E	30	PY59BF	WA-39-1020
39	WILSON CREEK	Temperature	17N	19E	31	PY59BF	WA-39-1020
39	YAKIMA RIVER	Temperature	20N	13E	10	EB21AR	WA-39-1070
39	YAKIMA RIVER	Temperature	20N	14E	36	EB21AR	WA-39-1060

The initial stream temperatures in the headwaters of the Yakima River are generally cool enough to meet State criteria, but the waters warm as they move downstream and violations of criteria become more common. Many factors can influence water temperature in a river system such as climate, flow, groundwater infusion, streambed gradient, exposure to solar radiation, subsurface flow, irrigation return, point-source outfalls, riparian shade and associated micro-climate, width/depth ratio, flow fluctuation, and solar aspect among others. Yakima Project operations may have a direct or an indirect effect on several of these parameters. Exposure to solar radiation is increased as riparian vegetation is impaired or removed, which often occurs along the river and its tributaries. Water is further exposed to radiation as it flows through canals, delivery ditches, and return drains which are specifically managed to exclude trees and other riparian growth. Artificially decreasing flows in the main stem channel on a daily basis allows exposed banks, bars, and boulders to accumulate heat that is released to the water column when flows are increased. The temperature of diverted irrigation water is increased as it flows overland across agricultural fields to re-enter the river as surface return flows. As water levels in the river and reservoirs are reduced as the irrigation season proceeds, the width/depth ratios increase, allowing more of the water volume to be exposed to solar radiation. Lower flows, resulting from water being diverted from the river system, also increase travel times, allowing river water to further collect heat.

Additionally and conversely, Yakima Project operations have been observed to acutely reduce temperatures by as much as 15 °F when gates at storage reservoirs are opened. This observation was made at the Cle Elum fish hatchery downstream of the Cle Elum Dam and Reservoir. In other river systems such reservoir releases are used to mediate temperature extremes in lower reaches. The possibility of incorporating this activity as a tool in the Yakima system needs to be explored.

The maximum temperature standard for Class AA streams is 16 °C (WAC, 1997). The general statewide standard for Class A streams is 18 °C, however, the main stem of the Yakima River (from the confluence with the Cle Elum River to the mouth) has a special standard of 21 °C. The WAC states that stream temperatures are not to exceed the maximums due to human activities. When stream temperatures do exceed the natural condition standard because of human activity no temperature increase greater than 0.3 °C is allowed.

USGS found that 12 percent of the 1,152 water temperature measurements from 192 sites during the 1986-91 water years exceeded the applicable State standards. These measurements were above standards for 26 percent of the measurements on Class AA streams, 13 percent on Class A streams, and 5 percent on Class B streams. If exceedances result from human activities they are considered violations of the State standards. Eighty percent of the 134 Class A exceedances were in the lower Yakima basin and included mostly main stem, tributary, canal, and drain sites. Much of the summer heating of the river water was associated with, (1) low flows downstream from the Wapato and Sunnyside Canal diversions, (2) slow stream velocities due to a small stream gradient between river miles (RM) 69.6 and 47.1, and (3) low flows between Prosser Dam and Chandler Pumping and Power Plant (Morace et al., 1999).

Payne and Monk’s (2001) water temperature modeling indicated that increased flows below Prosser Diversion Dam could influence mean and maximum daily water temperature under certain conditions and Carrol and Joy’s (2001) work supported these results.

6.1.1.5 Dissolved Oxygen

The DO content of a waterbody is affected by water temperature (warmer water holds less oxygen) and by the presence of oxygen-depleting substances, most notably bacteria and decaying organic material and even some chemicals (termed chemical oxygen demand or COD).

Most of the streams in the Yakima River basin are designated as Class A, in which DO shall exceed 8.0 mg/L. In Class AA streams (headwater streams and the Tieton River), DO shall exceed 9.5 mg/L. Sulphur Creek is the only stream in the basin designated as Class B, where the DO shall exceed 6.5 mg/L (WAC 173-201A-030, 1997).

During July 14-19, 1987, the USGS performed a synoptic sampling in which instantaneous DO was measured before or near sunrise to target minimum DO concentrations. Of the 39 sites sampled, nearly one-half failed to meet the State standards for DO. Most of these failures were measured in the lower Yakima basin, where the effects of agricultural return flow were noticeable. Of particular interest were the failures in the Granger/Sunnyside area, an area largely influenced by the large numbers of confined animal feeding operations (feedlots and dairies). Feedlot waste results in increased oxygen consumption due to the breakdown of the organic waste and nitrification of ammonia. The lower DO concentrations were also partly a function of warmer water temperatures (Morace et al., 1999).

6.1.1.6 Pesticides

Pesticides have been documented in basin return flows and drains associated with irrigated agriculture and in the main stem Yakima. Yakima Project Divisions have traditionally allowed the unrestricted return flow of agricultural tailwater into drains and tributaries. The return water has often been carrying high loads of suspended sediment and associated pesticides, such as DDT. The 1998 303(d) list gives evidence of a variety of pesticides found in the Yakima River and its agriculturally influenced tributaries (see table 6-4.).

Table 6-4.–1998 303(d) listings for pesticides in the Yakima River and its agriculturally influenced tributaries (WDOE, 1998).

WRIA	Waterbody Name	Parameter	Township	Range	Section	New ID #	Old ID#
37	GRANGER DRAIN	4,4'-DDD	10N	21E	21	KO70CH	WA-37-1024
37	GRANGER DRAIN	4,4'-DDE	10N	21E	21	KO70C	WA-37-1024
37	GRANGER DRAIN	DDT	10N	21E	21	EB21AR	WA-37-1024
37	GRANGER DRAIN	DDT	10N	21E	21	KO70CH	WA-37-1024
37	GRANGER DRAIN	Endosulfan	10N	21E	21	KO70CH	WA-37-1024
37	MOXEE DRAIN	4,4'-DDD	12N	13E	09	VE21WY	WA-37-1048
37	MOXEE DRAIN	4,4'-DDE	12N	13E	09	VE21WY	WA-37-1048
37	MOXEE DRAIN	Chlorpyrifos	12N	13E	08	VE21MH	WA-37-1048
37	MOXEE DRAIN	DDT	12N	13E	08	VE21MH	WA-37-1048
37	MOXEE DRAIN	DDT	12N	13E	09	TK46RP	WA-37-1048
37	MOXEE DRAIN	Endosulfan	12N	13E	08	YE21MH	WA-37-1048
37	MOXEE DRAIN	Endosulfan	12N	13E	09	TK46RP	WA-37-1048
37	SULPHUR CREEK	4,4'-DDD	09N	22E	24	YT62AF	WA-37-1030
37	SULPHUR CREEK	4,4'-DDE	09N	22E	24	YT62AF	WA-37-1030
37	SULPHUR CREEK	DDT	09N	23E	25	ZS24RD	WA-37-1030
37	SULPHUR CREEK	Endosulfan	09N	23E	25	ZS24RD	WA-37-1030
37	WIDE HOLLOW	4,4'-DDD	12N	19E	08	DY38VO	WA-37-1047
37	WIDE HOLLOW	4,4'-DDE	12N	19E	08	DY38VO	WA-37-1047
37	WIDE HOLLOW	DDT	12N	19E	08	EB21AR	WA-37-1047
37	WIDE HOLLOW	Dieldrin	12N	19E	08	EB21AR	WA-37-1047
37	YAKIMA RIVER	4,4'-DDD	09N	27E	19	EB21AR	WA-37-1010
37	YAKIMA RIVER	4,4'-DDE	09N	27E	19	EB21AR	WA-37-1010
37	YAKIMA RIVER	4,4'-DDE	10N	27E	03	EB21AR	WA-37-1010
37	YAKIMA RIVER	4,4'-DDE	11N	20E	20	EB21AR	WA-37-1020
37	YAKIMA RIVER	Arsenic	09N	22E	18	EB21AR	WA-37-1010
37	YAKIMA RIVER	Arsenic	09N	23E	34	EB21AR	WA-37-1010
37	YAKIMA RIVER	Arsenic	09N	27E	19	EB21AR	WA-37-1010
37	YAKIMA RIVER	DDT	09N	27E	19	EB21AR	WA-37-1010
37	YAKIMA RIVER	DDT	11N	20E	20	EB21AR	WA-37-1020
37	YAKIMA RIVER	Dieldrin	09N	27E	19	EB21AR	WA-37-1010
37	YAKIMA RIVER	Dieldrin	10N	27E	03	EB21AR	WA-37-1010
37	YAKIMA RIVER	Dieldrin	11N	20E	20	EB21AR	WA-37-1020
37	YAKIMA RIVER	Endosulfan	09N	27E	19	EB21AR	WA-37-1010
39	CHERRY CREEK	4,4'-DDE	17N	19E	29	FT68CJ	WA-39-1032
39	CHERRY CREEK	DDT	17N	19E	29	FT68CJ	WA-39-1032
39	CHERRY CREEK	Dieldrin	17N	19E	29	FT68CJ	WA-39-1032
39	YAKIMA RIVER	4,4'-DDE	16N	19E	33	EB21AR	WA-39-1010
39	YAKIMA RIVER	4,4'-DDE	20N	15E	27	EB21AR	WA-39-1030
39	YAKIMA RIVER	DDT	16N	19E	33	EB21AR	WA-39-1010
39	YAKIMA RIVER	DDT	20N	15E	27	EB21AR	WA-39-1030
39	YAKIMA RIVER	Dieldrin	16N	19E	33	EB21AR	WA-39-1010

In the 1989 USGS NAWQA it was determined that bottom fish in the lower Yakima River have some of the highest tissue concentrations of DDT in the country. These findings resulted in a Washington State Department of Health advisory in 1993, recommending that people limit consumption of bottom fish from the lower basin. The findings were a strong impetus for the development of the Lower Yakima River Suspended Sediment and DDT TMDL.

USGS found that, following pesticide applications in the spring, pesticide loads in the Yakima River were the highest when the soils were being eroded and transported by irrigation return flow and storm water runoff. They found that the flushing of compounds from soil-pore water, the eroding of soil-sorbed compounds, and the dissolving of compounds from soil and sediment into surface water are major pathways for pesticides to travel from agricultural fields to streams and their aquatic biota.

USGS also found that the irrigated agricultural land east of the Yakima River and downstream from the City of Yakima was the predominant source area for suspended sediment and pesticides in the basin during the irrigation season. This area had the largest acreage of irrigated land and generally received the largest application of pesticides. They also found that concentrations of t-DDT detected in agricultural soil samples were higher than those in suspended sediment and streambed sediment samples, which suggests that eroding soils from agricultural land were a major source of t-DDT to the streams and the river.

In 1989, 54 different agricultural pesticide compounds were analyzed in the NAWQA study, and 43 of the 54 compounds analyzed (80%) were detected at trace or quantifiable concentrations in soil, bed sediment, suspended sediment, water, and (or) aquatic biota at 1 or more sampling sites (Morace et al., 1999).

In 1995, WDOE analyzed whole water samples for 46 pesticides at the Granger Drain, Spring Creek, Sulphur Creek, and the Yakima River (at Euclid Bridge) as part of the TMDL evaluation. Organochlorine, organophosphate, and nitrogen-containing pesticides were frequently detected at all sites. Azinphos methyl was detected multiple times at concentrations above criteria at all four sites. Total DDT was detected above the human health and aquatic chronic toxicity criteria at all sites on three or more sampling dates. The t-DDT samples analyzed had concentrations from 0.004 mg/L to 0.357 mg/L, and a median of 0.0083 mg/L. The median concentration, and most sample results, was similar to what has been reported in recent years for these sites (Joy and Patterson, 1997).

6.1.1.7 Nutrients

Nutrients (nitrate/nitrite nitrogen, ammonia nitrogen, and phosphorus) enter the Yakima River and its tributaries primarily via agricultural return flows, many of which originate as water from the Yakima Project. There are no State standards for phosphorus or nitrate/nitrite nitrogen in free-flowing waterbodies. There are, however, standards for these nutrients in lakes. Giffin Lake, near Sunnyside, which receives return flows from agriculture, is 303(d) listed for phosphorus. There are also 2 waterbody segments of the Yakima River and its tributaries 303(d) listed for ammonia nitrogen (WDOE, 1998), which can be a conversion product of nitrate/nitrite nitrogen at high pH levels.

USGS found that the median total nitrogen and total phosphorus concentrations were 8 and 19 times larger, respectively, at agricultural sites than at forested sites. The pattern of low concentrations from forest-dominated sites and high concentrations from agriculturally dominated sites emphasizes the significance of agricultural activities on water quality throughout the Yakima

River basin. The large downstream increase (factor of 10) in total nitrogen concentrations between Cle Elum and Kiona emphasizes the impact of agricultural practices on water quality in the lower and mid-river basin. For the most part sewage from municipal treatment plants and septic tank sources plays a less significant role. The presence of a large proportion of the total nitrogen as nitrite plus nitrate is significant because nitrite and nitrate are readily used by algae and rooted aquatic plants. Such aquatic growth was present downstream near Sunnyside (Morace et al., 1999).

Total phosphorus concentrations also increased by a factor of 10 between Cle Elum and Kiona, with concentrations ultimately ranging from 0.1 to 0.2 mg/L between Grandview and Kiona. Phosphorus associated with suspended sediment washed from agricultural fields was considered a significant source. Sulphur Creek provided a significant input of phosphorus to the main stem (Morace et al., 1999).

6.1.1.8   Fecal Coliform Bacteria

FC are used as an indicator of pathogens that cause human-borne diseases such as cholera, typhoid fever, and bacillary and amoebic dysentery. It can also be a problem in itself, with certain strains causing severe gastro-intestinal disorders. FC are generally not considered a direct by-product of irrigated agriculture. However, in the lower Yakima basin the spreading of manure from dairy operations on irrigated lands is employed as a method of waste disposal. High volumes of manure and water are often applied to lands that are directly connected to surface drains or underlain by subsurface tile drains. Irrigated pasture and rangeland that is carelessly managed can also contribute to FC contamination of surface waters. Current Yakima Project operations of the Yakima River and its irrigation delivery and return system has resulted in FC contamination of the river and its tributaries by allowing the discharge and return of contaminated waters to the river system. The WDOE's Granger Drain TMDL (publication 01-10-012) determined that increases of FC in the Granger Drain, a major irrigation return drain tributary to the lower Yakima River, were directly correlated with increases in suspended sediment concentrations.

Twelve waterbody segments in the Yakima River and in tributaries directly impacted by agricultural runoff are on the 1998 303(d) list for FC (WDOE, 1998) (see table 6-5.).

Table 6-5.–1998 303(d) listings for Fecal Coliform

WRIA	Waterbody Name	Parameter	Township	Range	Section	New ID #	Old ID #
37	Granger Drain	Fecal Coliform	10N	21E	21	EB21AR	WA-37-1024
37	Moxee Drain	Fecal Coliform	12N	13E	08	DY38VO	WA-37-1048
37	Wide Hollow Creek	Fecal Coliform	12N	19E	06	DY38VO	WA-37-1047
37	Wide Hollow Creek	Fecal Coliform	12N	19E	07	DY38VO	WA-37-1047
37	Wide Hollow Creek	Fecal Coliform	12N	19E	08	DY38VO	WA-37-1047
37	Wide Hollow Creek	Fecal Coliform	12N	19E	35	DY38VO	WA-37-1047
37	Yakima River	Fecal Coliform	09N	22E	25	EB21AR	WA-37-1010
37	Yakima River	Fecal Coliform	12N	19E	17	EB21AR	WA-37-1040
39	Cooke Creek	Fecal Coliform	17N	19E	10	SZ58XV	WA-39-1034
39	Cooke Creek	Fecal Coliform	17N	19E	11	SZ58XV	WA-39-1034
39	Wilson Creek	Fecal Coliform	17N	18E	25	EB21AR	WA-39-1020
39	Wilson Creek	Fecal Coliform	18N	19E	30	PY59BF	WA-39-1020

During a 1988 synoptic study, the USGS focused on *E. coli* contamination. They found that land use was an important correlative factor in the distribution of *E. coli* concentrations in the Yakima River basin. Median *E. coli* concentrations increased among land use categories in the following order: forest, range land, agriculture, and agricultural drains. Statistically significant differences existed among these categories (Morace et al., 1999).

The 1999 USGS Bacterial Synoptic Survey showed a significant increasing trend in bacterial densities when moving downstream in the main stem Yakima River from Cle Elum (3 cfu/100 ml) to Kiona (131 cfu/100 ml). The trend was associated to a respective land use change from forests to a highly agricultural area. The highest FC densities in all of the basin's tributaries were found within three agricultural drains in the lower basin. The Moxee Drain had 1,760 cfu/100 ml, the Granger Drain had 1,950 cfu/100 ml, and Sulphur Creek had 1,400 cfu/100 ml.

The 2000 USGS Bacterial Synoptic Survey, which occurred during both the irrigation and non-irrigation seasons, determined bacterial densities increased proportionately to the amount of agricultural activity throughout the basin.

6.1.1.9 pH

Stream pH may change with the addition of either acidic or alkaline wastes and (or) fluctuations in photosynthesis and respiration (due to the uptake and release of carbon dioxide by aquatic plants). Toxicity to freshwater aquatic life can occur whenever pH values fall outside the range of 6.5 to 8.5, which corresponds to the water quality standards set by WAC 173-201A-030 for Class AA, A, and B waterbodies. As pH increases (becomes more alkaline), the ammonium ion is dissociated to the toxic unionized ammonia form, potentially causing greater harm to aquatic life.

Normal operations of the Yakima Project may indirectly result in pH violations of State criteria. Low water volume in the Yakima River from project operations and high nutrient loading from agricultural return drains can promote plant growth in the river. As the plants grow and respire they may cause pH values to fall outside of the range normally experienced by the aquatic community. This may lead to changes in the aquatic community or avoidance areas for certain species.

There are 3 agriculturally influenced waterbodies in the lower Yakima Valley that are listed for pH on Washington State's 303(d) list; these are the Moxee Drain, the Granger Drain, and the main stem of the Yakima River (WDOE, 1998). Additionally, the USGS found that 11 percent of the 856 pH measurements from 143 sites sampled by the USGS in the Yakima basin during the 1986-91 water years did not meet State water quality criteria. Ninety-seven percent of these exceedances had pH values greater than 8.5 (those below 6.5 came from forested streams in the upper basin). Most exceedances were probably the result of increased photosynthetic activity from aquatic plants. Downstream from Satus Creek, all median pH values were greater than 8, probably due to the influence of agricultural inputs, irrigation diversions, and aquatic vegetation in this reach (Morace et al., 1999).

6.1.2 **Quantity** (As a relationship between regulated and natural hydrologic conditions)

All river flow derives from precipitation, either rain or snow. At any given time river flow is some combination of surface water, shallow subsurface flow (hyporheic), and groundwater. Overland and shallow subsurface flow creates hydrograph peaks, a river's normal response to storm events or snowmelt. Groundwater pathways are responsible for baseflow, the form of water delivery to river systems during periods of little rainfall and after snowmelt has dissipated.

Variability in intensity, timing and duration of precipitation, and variability in the effects of terrain, soil texture, and plant evapotranspiration on the hydrologic cycle combine to create local and regional flow patterns in river basins. High flows from rain may occur over hours or even minutes, whereas snow will melt over a period of days or weeks, more slowly building the peak snowmelt flood. Both of these processes occur in the Yakima River basin.

As one proceeds downstream within a watershed, river flow reflects the sum of flow generation and routing processes operating in multiple small tributary watersheds. The travel time of flow down the river system, combined with unsynchronized tributary inputs and larger downstream channel and floodplain storage capacities, act to attenuate and to dampen flow peaks. Consequently, annual hydrographs in large streams typically show peaks created by widespread storms or snowmelt events and broad seasonal influences that effect many tributaries together.

The natural flow regime organizes and defines river ecosystems. The availability and diversity of habitats is determined by physical processes, especially the movement of water and sediment within the channel, and between the channel and floodplain. To understand the biodiversity, production, and sustainability of river ecosystems, it is necessary to appreciate the central organizing role played by a dynamically varying physical environment. Different habitat features are created and maintained by a wide range of flows. For example, many channel and floodplain features, such as river bars and riffle-pool sequences, are formed and maintained by dominant, or bankfull discharges. These discharges are flows that can move significant quantities of bed or bank sediment and that occur frequently enough (e.g., every several years) to modify the channel continually. Over periods of years to decades, a single river can consistently provide ephemeral, seasonal, and persistent types of habitat that range from free-flowing, to standing, to no water. This predictable diversity of in-channel and floodplain habitat types promotes evolution of species that exploit the habitat mosaic created and maintained by hydrologic variability. For many riverine species, including anadromous and resident salmonids, completion of the life cycle requires an array of different habitat types, the availability of which is regulated by the flow regime.

The pattern of spatial and temporal habitat dynamics influences the relative success of a species. This habitat template, which is dictated largely by flow regime, creates both subtle and profound differences in the natural histories of species in different segments of their ranges and it also influences their distribution and abundance. Human alteration of flow regime changes the established pattern of natural hydrologic variation and disturbance, thereby altering habitat dynamics and creating new conditions to which the native species may or may not be able to adapt or to which they may poorly adapt. We will refer to these processes generally in the sections that follow as “natural flow variability.”

River basins, such as the Yakima basin, that are regulated for irrigation and flood control purposes exhibit a common set of hydrologic patterns. Natural flows, usually produced from precipitation during the early winter and snowmelt during the late winter and spring/summer operation periods, are captured for storage. Downstream of major storage facilities, winter outflows can be greatly reduced, with major variations to natural hydrologic conditions. Peaking natural flows from rain, or rain-on-snow events, causing “flood events,” are captured in available storage and bypassed later during a lower flow period in the downstream basin. Therefore, magnitude and frequency of ecologically significant discharges (overbank and channel-forming flows) are reduced.

Patterns of summer and fall flows are largely influenced by downstream irrigation demands with flows typically reaching peaks during July and August above the major diversions. Below these major diversions, streamflow can be low even to the point of being below natural flows. Unnatural fluctuations in flow and temperature may result from adjustments in reservoir releases intended to meet fluctuating irrigation demands downstream, and also, may result from the discharge of irrigation return flows to the river alone or in combination with other return flow discharges or reservoir releases (Poff et al., 1997).

Changes in the rate and magnitude of discharge that are caused by project operations will be referred to in this document as “operational fluctuations” or “ramping,” as opposed to those that occur under natural hydrologic conditions, which will be referred to as “natural flow variability.”

The effects of project operations on water quantity vary by reach locations and timing throughout the Yakima River basin (see table 6-6.). In order to describe and understand these effects, it is necessary to examine the differences between regulated and estimated unregulated (natural) flows at a number of key locations. These key locations data are represented by summary hydrographs, which break the data into two time periods. The first time period, water years 1981 to 1999, represents the data from project operations that developed out of the 1980 Quackenbush decision concerning the protection of anadromous fish in the Yakima River (the start of the flip-flop operation). The second time period, water years 1995 to 1999, represents current project operations, including meeting Title XII target flows, that have evolved during the past 5 years of operations.

It is noteworthy that for the Yakima River near Parker (PARW), period of record 1981 to 1999, water year (WY) 1996 (5,586,144 acre-feet) and WY 1997 (5,316,350 acre-feet) had the highest and second highest yearly natural unregulated streamflow (runoff) totals for the 19 year period. WY 1999 (4,382,610 acre-feet) was 1 million acre-feet above average (3,390,550 acre-feet), with WY 1995 (3,765,652 acre-feet) above average, and WY 1998 (3,373,299 acre-feet) slightly below average. Even though the majority (4 years out of 5) of the 1995-1999 period of record water years had above average runoff, 3 of the 5 water years (1995, 1996, and 1998) had below average total storage (average is 301,246 acre-feet) on September 30th. This is an indicator that other parameters or factors, such as amount of carryover storage; flood runoff timing; snowpack and melt pattern; rain fall timing; and local basin weather conditions must be reviewed in order to fully characterize a water year.

These summary hydrographs are developed using mean or average data, which tends to minimize the hydrologic flow fluctuations that occur in any given year. Therefore, some sites are provided with hydrographs plotting individual water year data that are representative of a typical (but not necessarily average) year, WY 1990; a dry year, WY 1994; and a wet year, WY 1997. These water years do not represent extreme or unusual runoff conditions, but years of typical/normal runoff patterns with only the volume of runoff being consistently uniformly greater or less than a typical/average year. We chose the most recent years that provided uniform dispersal of precipitation, snowpack, and timing of melt/runoff as representative water years. With relatively uniform wet runoff conditions, WY 1997 had the 4th highest annual runoff volume of the period of record. A typical year is represented by 1990, which had average or mean runoff conditions throughout the year, providing close to average annual runoff volume for the year. The dry year, WY 1994, had uniformly low precipitation, snowpack, and consistent low runoff, placing it 4th lowest in annual total volume for the period of record.

Table 6-6.–Examined reach locations

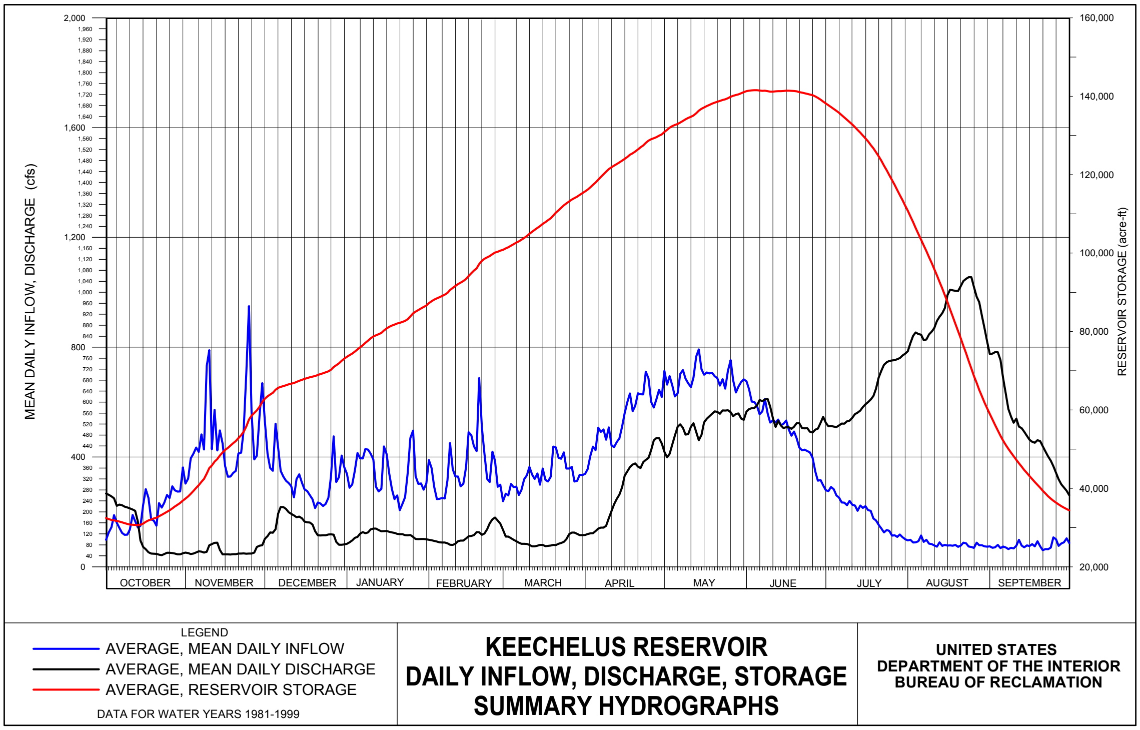
Reach Location	River Mile	Drainage Area (mi.^{2})	Drainage Area as % of Yak @ PARW	Average Annual Unregulated Flow (AF)	Ave. Annual Unreg. Flow as % of Yak @ PARW	Ave. Annual actual flow (AF)
Keechelus	214.5	54.7	1.5	247,302.	7.3	245,705.
Kachess	0.9	63.6	1.7	218,394.	6.4	215,885.
Yak. R. @ Easton	202.0	188.0	5.1	651,710.	19.2	325,499.
Cle Elum	8.2	203.0	5.5	675,373.	19.9	661,600.
Yak. R. @ Cle Elum	183.1	495.0	13.5	1,495,088.	44.1	1,164,965.
Teanaway River	9.6	172.0	4.7	245,968.	7.3	245,968.
Yak. R. nr. Umtanum	140.4	1,594.0	43.5	1,976,094.	58.3	1,731,876.
Yak. R. below Roza Dam	127.7	1,802.0	49.2	NA	NA	Incomplete
Bumping	17.0	69.3	1.9	205,461.	6.1	205,159.
Little Naches River	0.1	125.4	3.4	181,895.	5.4	181,895.
Naches R. nr. Cliffdell	36.3	394.0	10.8	NA	NA	657,167.
Rimrock	21.3	187.0	5.1	369,323.	10.9	366,647.
Tieton R. below Canal Hdwks.	14.1	239.0	6.5	NA	NA	309,915.
Naches R. nr. Naches	16.8	941.0	25.7	1,199,029.	35.4	870,067.
Yakima R. @ Terrace Heights	113.2	NA	NA	NA	NA	Incomplete
Yakima R. nr. Parker - TWSA	103.7	3660.0	100.0	3,390,551.	100.0	1,654,918.
Yakima R. nr. Grandview	55.0	5410.0	-	NA	-	1,975,288.
Yakima R. nr. Prosser	46.3	5453.0	-	NA	-	1,594,751.
Yakima R. nr. Kiona	29.9	5615.0	-	*3,970,000.	-	2,351,186.
Yakima R. @ Mouth @ Col. R.	0.0	6155.0	-	NA	-	NA
System – Total 5 Reservoirs	NA	579.0	15.8	1,713,282.	50.5	1,694,349.

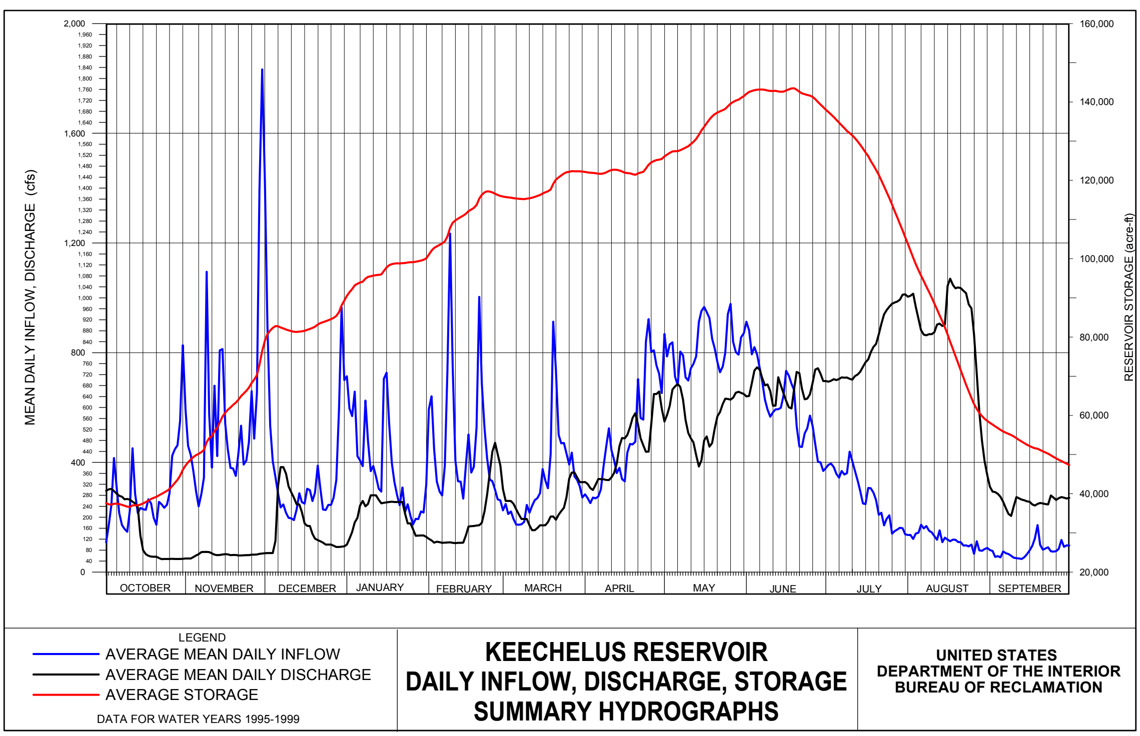
(Provisional Data for Water Year -- Period of Record = 1981-1999, if available) 11/7/2000 SKF

NA = Data currently Not Available. * = Period of Record = 1961-1990

Normally, Keechelus natural inflows start increasing mid-October, continuing to increase until late November. Cold weather will then lock up the rain and snowfall causing a decline and stabilizing effect on the inflow to the reservoir. In March, inflows will once again start increasing and will continue to increase until late May or June. Late June, early July, inflow will start declining to the low period of August and September. Natural flows are captured during the winter and spring/summer periods for storage, targeting June 1st for maximizing storage content of the reservoir. (Note: Keechelus is currently operating under safety of dams restriction on maximum elevation.) Discharges (reservoir outflow) are made during the winter for protection of the downstream fishery resources and to provide flood control storage space during the November to early May period. Irrigation demands on the storage/inflow will normally begin in April and continue through August when storage releases are reduced ("mini flip-flop") to provide spawning flows that are maintainable during the winter incubation period. The comparison of natural inflow and reservoir discharge reflect a lower than natural flow, but stable outflow during October and November; with December through March still reflecting a lower outflow than natural, but with more variability due to flood control operations. April through June outflows tend to mirror inflow patterns, but at a reduced quantity (due to flood control operations), with the inflow/outflow relationship coming closest to matching during June as storage is maximized and the natural runoff is peaking. Currently, the maximum discharge releases are made during July and August (95,646 acre-feet) for irrigation demands. Of the 247,302 acre-feet average annual natural (unregulated) flow generated in the Keechelus basin, 131,421 acre-feet (53%) is delivered/released during July 1st through October 20th, to meet system demands during the normal period of low natural flows. Note that 103,867 acre-feet of this delivery is from the storage component of the water supply.

Keechelus


MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, MEAN DAILY INFLOW
AVERAGE, MEAN DAILY DISCHARGE
AVERAGE, RESERVOIR STORAGE
DATA FOR WATER YEARS 1981-1999
KEECHELUS RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
OCTOBER
NOVEMBER
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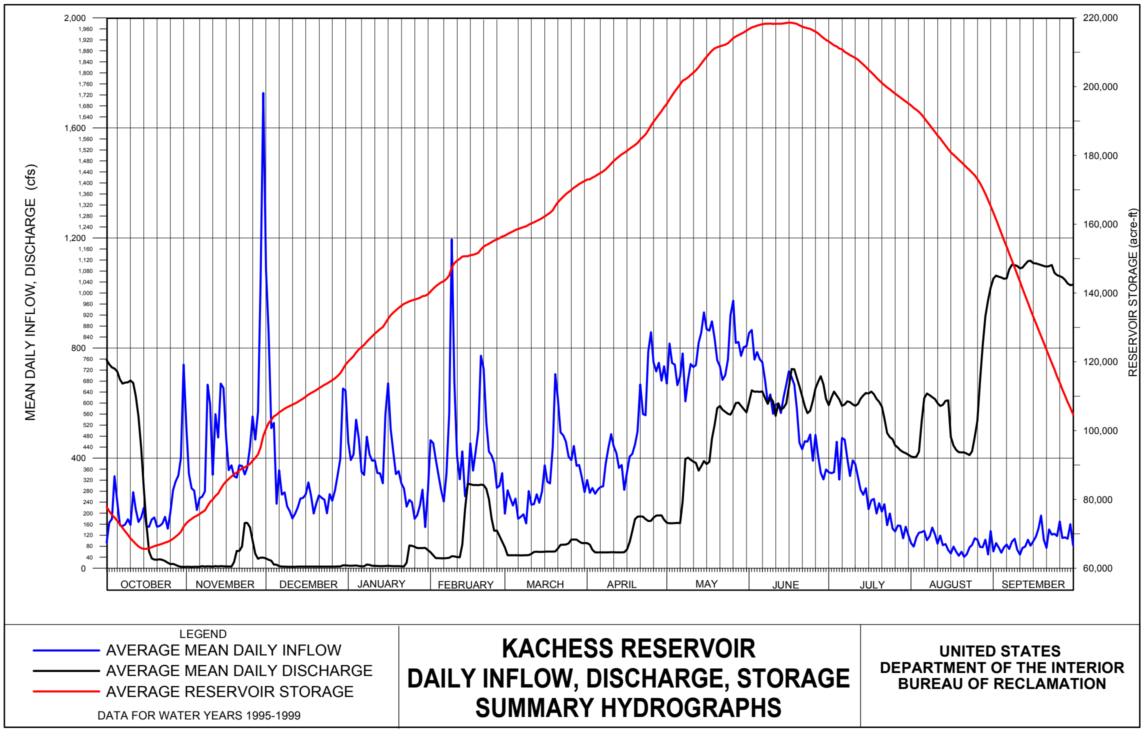
SEPTEMBER
LEGEND
AVERAGE MEAN DAILY INFLOW
AVERAGE MEAN DAILY DISCHARGE
AVERAGE STORAGE
DATA FOR WATER YEARS 1995-1999
KEECHELUS RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Normally, Kachess natural inflows start increasing mid-October, continuing to increase until late November. Cold weather will then lock up the rain and snowfall causing a decline and stabilizing effect on the inflow to the reservoir. In March, inflows will once again start increasing and will continue to increase until late May or June. Mid-June inflow will start declining to the low period of August and September. Natural flows are captured during the winter and spring/summer periods for storage, targeting June 1st for maximizing storage content of the reservoir. Due to the poor runoff to storage capacity (.9 to 1) discharges (reservoir outflow) are made (but minimized) during the winter for protection of the downstream fishery resources and also to provide flood control operations storage space during the November to early May period if the runoff forecast shows justification. Moderate irrigation demands on the storage/inflow will normally begin in mid-April and continue through August when storage releases are increased for irrigation demands above Easton Dam, during the mini flip-flop operation to replace cutbacks of Keechelus outflows. The comparison of natural inflow and reservoir discharge reflects a lower than natural flow, but stable outflow from mid-October through March with only minimal variability due to flood control operations. April through June outflows tend to reflect inflow patterns, but at a much reduced quantity (due to flood control operations), with the inflow/outflow relationship coming closest to matching early June as storage is maximized and the natural runoff is peaking. Currently, the maximum discharge releases are made during late August and September for irrigation demands. Of the 218,394 acre-feet average annual natural (unregulated) flow generated in the Kachess basin, over 146,477 acre-feet (67%) is delivered/released during July 1st through October 20th to meet system demands on storage during the normal period of lowest natural flows. During the July 1st through October 20th period, 124,055 acre-feet of this delivery is from the storage component of water supply.

Kachess


MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
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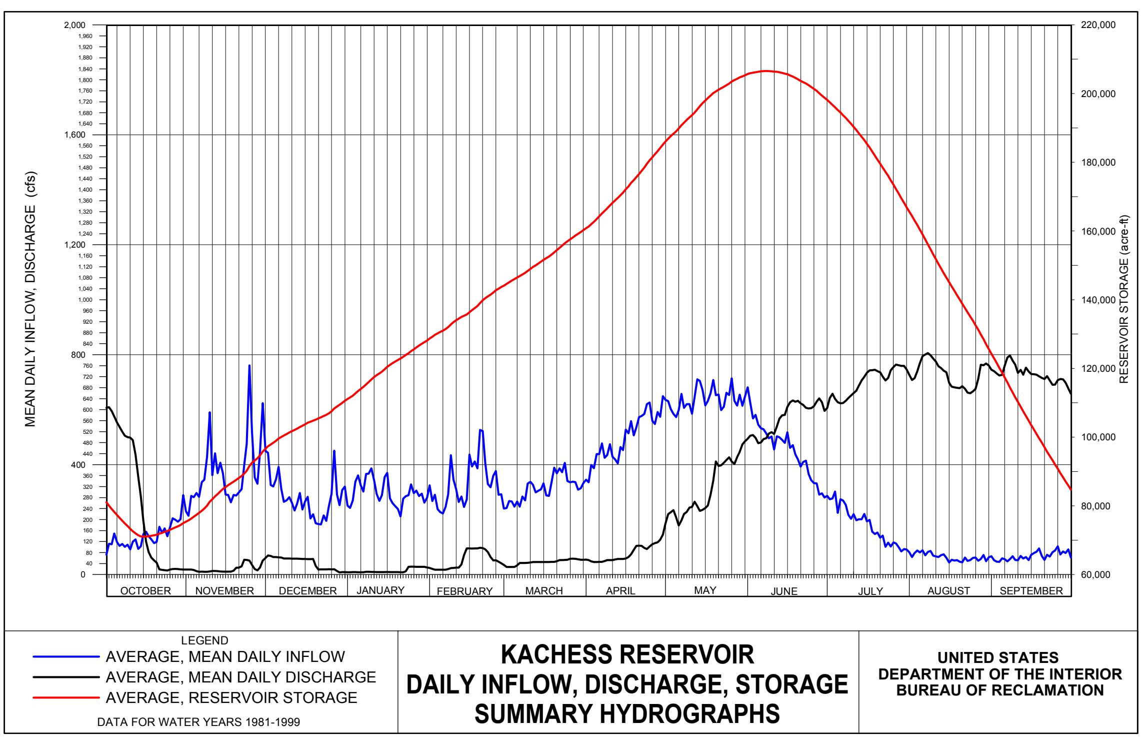
AVERAGE MEAN DAILY INFLOW
AVERAGE MEAN DAILY DISCHARGE
AVERAGE RESERVOIR STORAGE
DATA FOR WATER YEARS 1995-1999
KACHESS RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, MEAN DAILY INFLOW
AVERAGE, MEAN DAILY DISCHARGE
AVERAGE, RESERVOIR STORAGE
DATA FOR WATER YEARS 1981-1999
KACHESS RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
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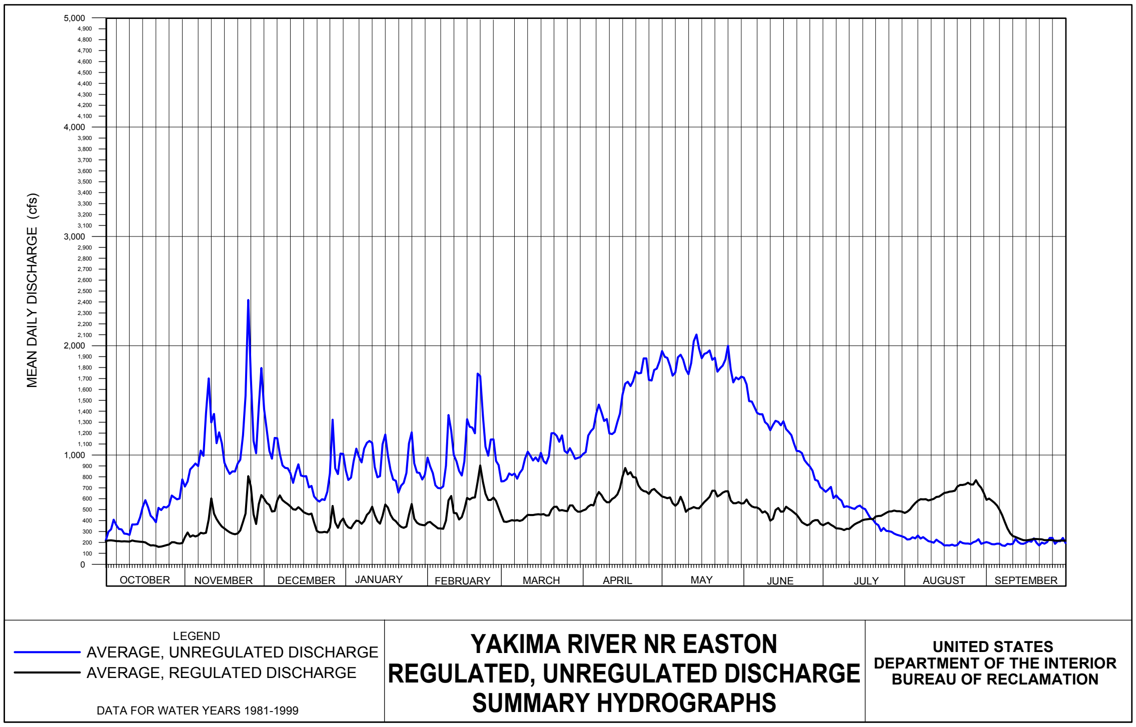
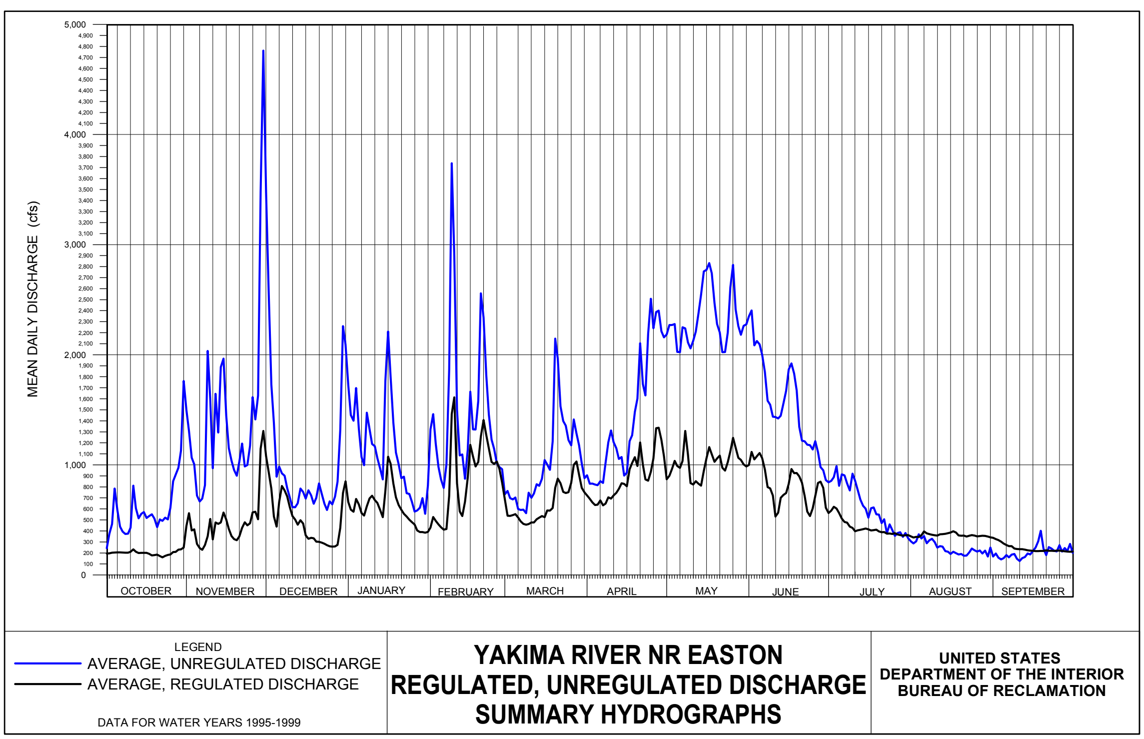
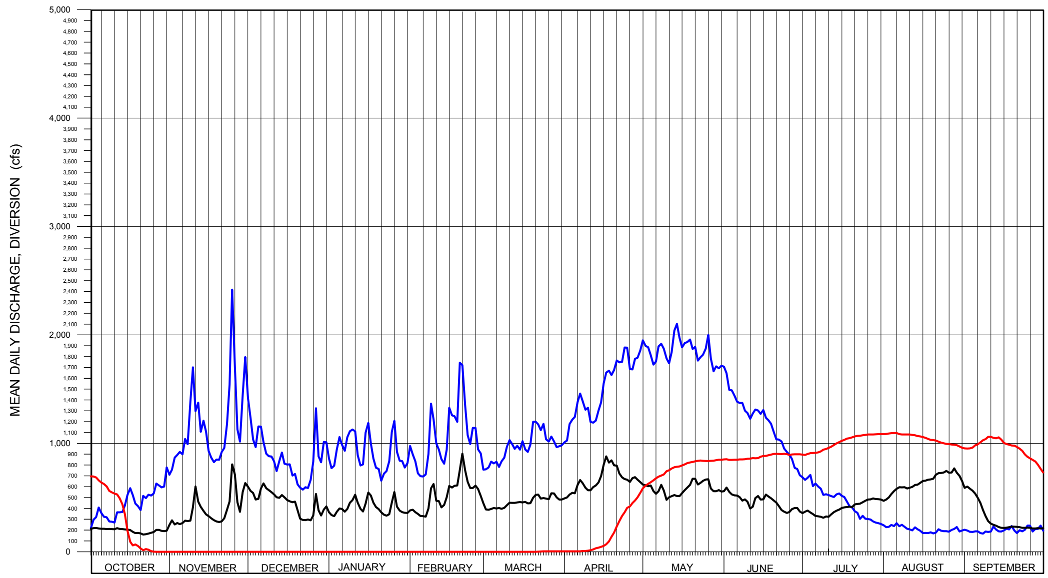
BUREAU OF RECLAMATION

Yakima River near Easton natural unregulated streamflow starts increasing mid-October through November as fall precipitation increases. Natural flows recede to winter conditions as freezing conditions in upper watersheds reduce runoff. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. Regulated streamflow is below unregulated conditions and does not show the peaks due to reservoir inflows captured in storage. During the December through February period, the discharge is stable except for rain-on-snow events that formed the short duration, high discharges on a relatively infrequent basis. Regulated winter streamflow is lower than natural conditions and the frequency and magnitude of peak flows is reduced due to reservoir operations for flood control and storage. March natural flows begin to increase and continues through mid-May. Unregulated streamflow forms the average annual peak discharge from early April through early June. From mid-April through June, regulated streamflow shows a greatly reduced peak as Kittitas Reclamation Canal irrigation deliveries begin to increase. Current project practice for flood control operations allows for maximizing storage in late May, early June, and after this time the bypassing of reservoir natural inflows to the river system, returning some of the natural variability to the river system. Beginning early June through late July, unregulated streamflow will decline from spring freshet to baseflow conditions. Currently, regulated flow only exceeds unregulated starting in mid-July through August (or until start of flip-flop) as some storage flows are wheeled to meet downstream irrigation demands and may only be 100 to 200 cfs greater than unregulated. The estimated average natural unregulated flow from late July through early October is 200 cfs per day. From September 1st through October 20th, streamflows are held to spawning level and fluctuate very little under natural conditions, but currently regulated flows drop from highs in late August (400 cfs) to early September (200 cfs) after flip-flop. The Yakima River near Easton (EASW) basin average annual natural flow is 651,710 acre-feet, of which 465,696 acre-feet (71%) is regulated by storage reservoirs capable of modifying the timing and volume of flows at the EASW site. The Kittitas Canal Diversion (located above EASW site), diverts on the average 310,670 acre-feet of flow with the peak diversion, including water bypassed for flip-flop in September and October, of 361,450 acre-feet for the past 19 years. EASW unregulated hydrograph is compared with a typical year, WY 1990; a dry year, 1994; and a wet year, 1997, as an indicator of the effect of climatological conditions on natural unregulated flow/discharge. EASW unregulated and regulated hydrograph is compared with the diversion discharge hydrograph of the Kittitas Reclamation Canal to show the diversion demands on natural flow and storage affecting EASW discharges. Also included is a hydrograph comparing the unregulated natural flows of the two reservoir sites, Keechelus and Kachess, with the local natural inflow above EASW excluding the reservoirs outflow, and the total unregulated discharge of the EASW site.

Yakima River near Easton







LEGEND

AVERAGE, UNREGULATED DISCHARGE

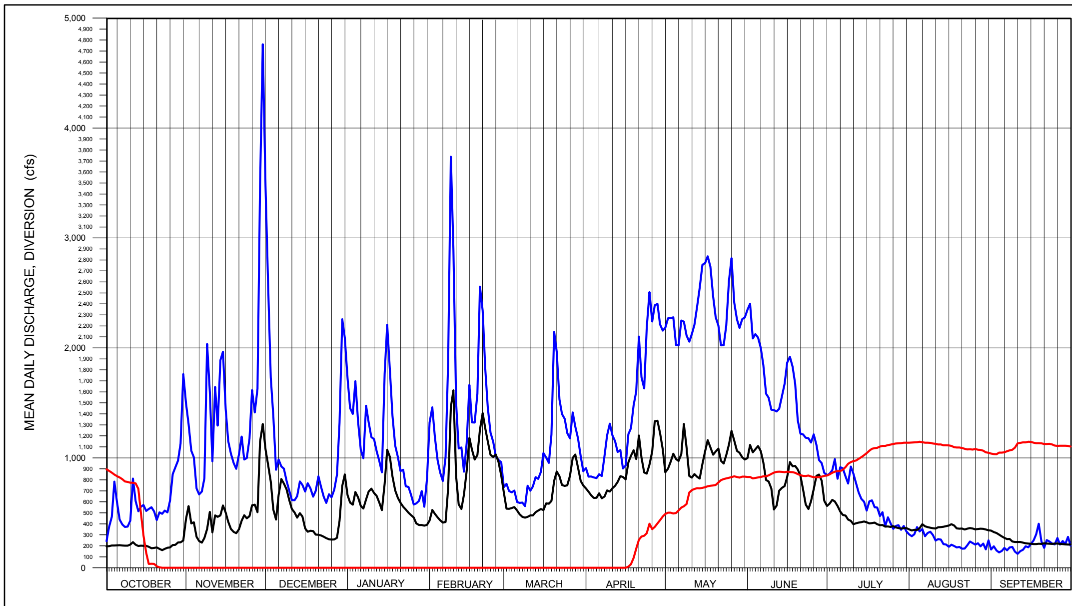
AVERAGE, REGULATED DISCHARGE

AVERAGE, KRD DIVERSION

DATA FOR WATER YEARS 1981-1999

YAKIMA RIVER NR EASTON, KRD DISCHARGES AND DIVERSON SUMMARY HYDROGRAPHS

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION



LEGEND

AVERAGE, UNREGULATED DISCHARGE

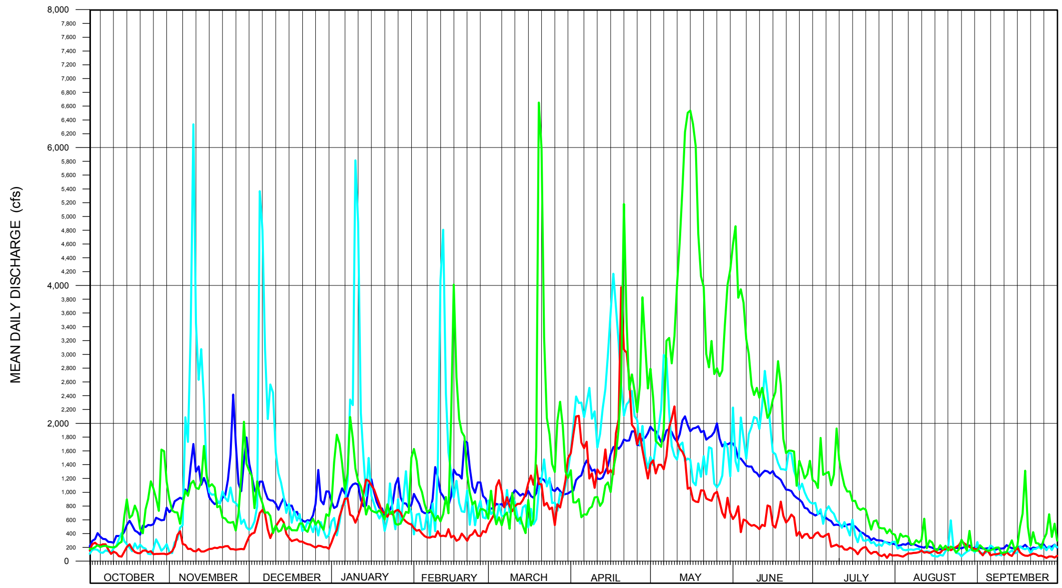
AVERAGE, REGULATED DISCHARGE

AVERAGE, KRD DIVERSION

DATA FOR WATER YEARS 1995-1999

YAKIMA RIVER NR EASTON, KRD DISCHARGES, DIVERSION SUMMARY HYDROGRAPHS

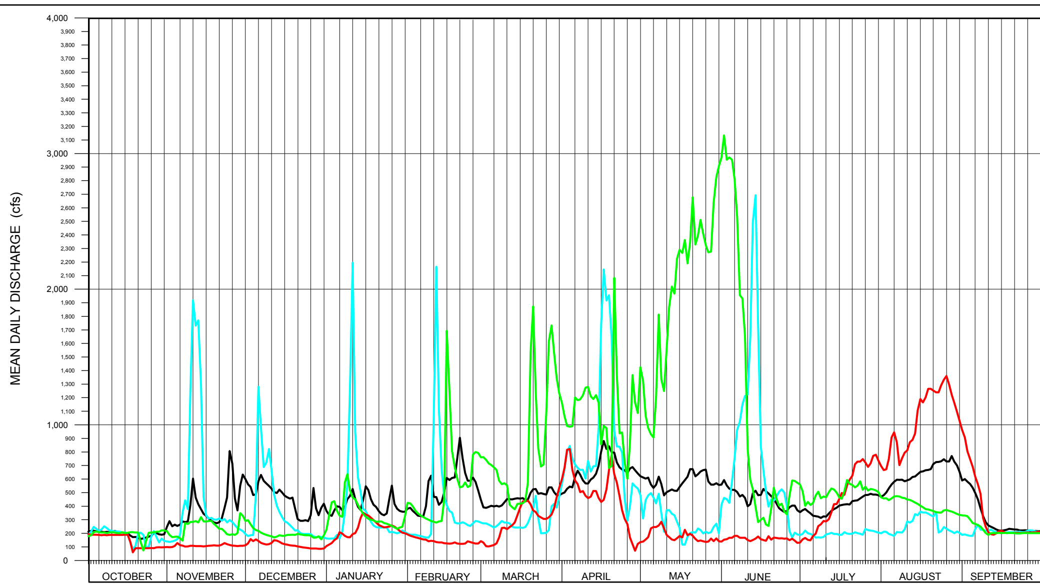
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION



LEGEND
- AVERAGE, UNREGULATED DISCHARGE, WY 1981-1999
- TYPICAL YEAR, 1990
- DRY YEAR, 1994
- WET YEAR, 1997

YAKIMA RIVER NR EASTON
UNREGULATED DISCHARGE
SUMMARY HYDROGRAPHS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION



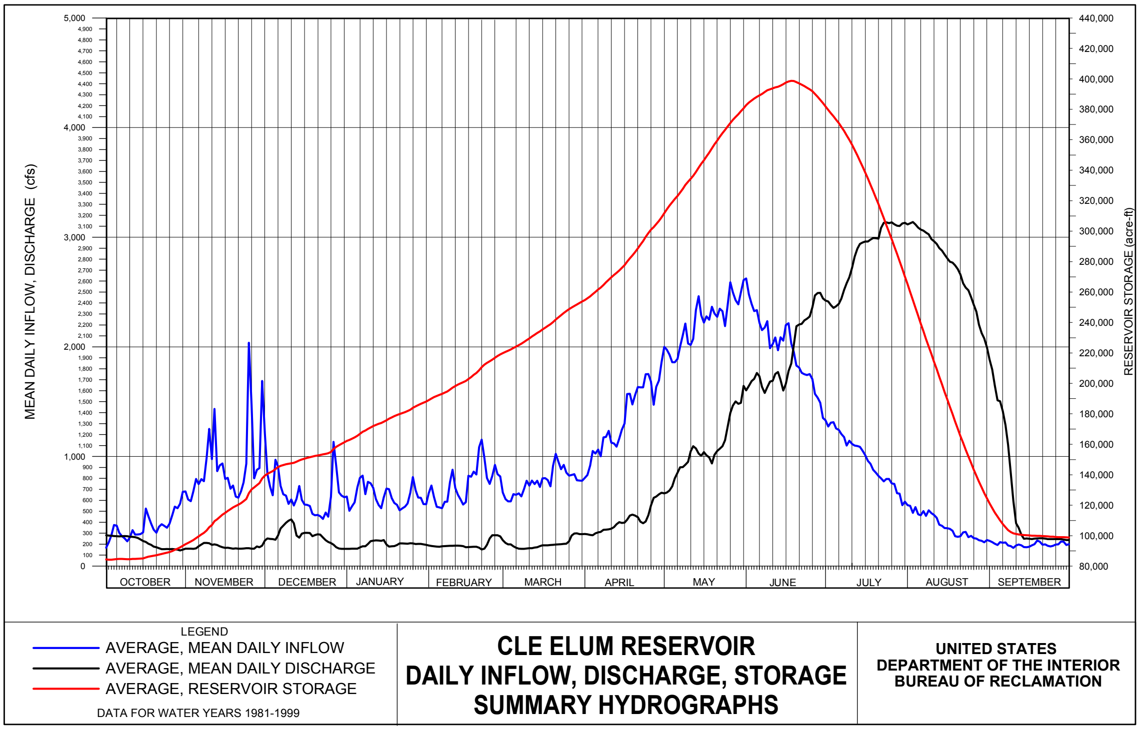
LEGEND
- AVERAGE, REGULATED DISCHARGE, WY 1981-1999
- TYPICAL YEAR, WY 1990
- DRY YEAR, WY 1994
- WET YEAR, 1997

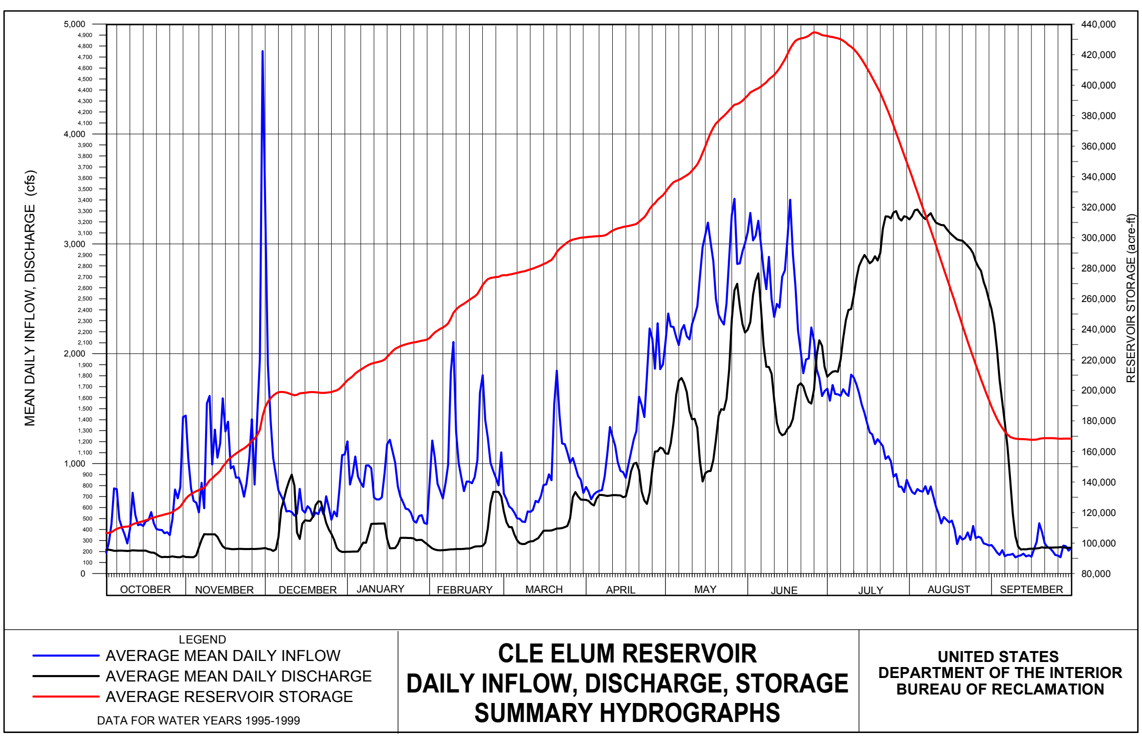
YAKIMA RIVER NR EASTON
REGULATED DISCHARGE
SUMMARY HYDROGRAPHS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

As in the other reservoir basins, Cle Elum natural inflows start increasing mid-October, continuing to increase until late November. It is common to have a rain induced flood event at the end of November or early December. Cold weather will then lock up the rain and snowfall causing a slight decline and stabilizing effect on the inflow to the reservoir. In March, inflows will once again start increasing and will continue to increase until late May or June. Late June, early July, inflow will start declining to the low period of late August and September. Natural flows are captured during the winter and spring/summer periods for storage, targeting June 1st for maximizing storage content of the reservoir. Discharges (reservoir outflow) are made during the winter for protection of the downstream fishery resources and to provide flood control operations storage space during the November to early May period. Irrigation demands on the storage/inflow will normally begin in April and continue through September 10th when storage releases are reduced (flip-flop) to provide downstream spawning flows that are maintainable during the winter incubation period. The comparison of natural inflow and reservoir discharge reflect a lower than natural flow, but stable outflow during October and November; with December through March still reflecting a much lower outflow than natural, but with more variability due to flood control operations. April through June outflows tend to mirror inflow patterns, but at a reduced quantity (due to storage and flood control operations), with the inflow/outflow relationship coming closest to matching during June as storage is maximized and the natural runoff is peaking. Currently, the maximum discharge releases are made during July through September 10th (375,872 acre-feet) for irrigation demands. Of the 675,373 acre-feet average annual natural (unregulated) flow generated in the Cle Elum basin, 385,721 acre-feet (57%) is delivered/released during July 1st through October 20th to meet system demands during the normal period of low natural flows. During the July 1st through October 20th period, 281,057 acre-feet of this delivery is from the storage component of the water supply.

Cle Elum


MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
0
1,000
2,000
3,000
4,000
5,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
220,000
240,000
260,000
280,000
300,000
320,000
340,000
360,000
380,000
400,000
420,000
440,000
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, MEAN DAILY INFLOW
AVERAGE, MEAN DAILY DISCHARGE
AVERAGE, RESERVOIR STORAGE
DATA FOR WATER YEARS 1981-1999
CLE ELUM RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
0
1,000
2,000
3,000
4,000
5,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
220,000
240,000
260,000
280,000
300,000
320,000
340,000
360,000
380,000
400,000
420,000
440,000
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE MEAN DAILY INFLOW
AVERAGE MEAN DAILY DISCHARGE
AVERAGE RESERVOIR STORAGE
DATA FOR WATER YEARS 1995-1999
CLE ELUM RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
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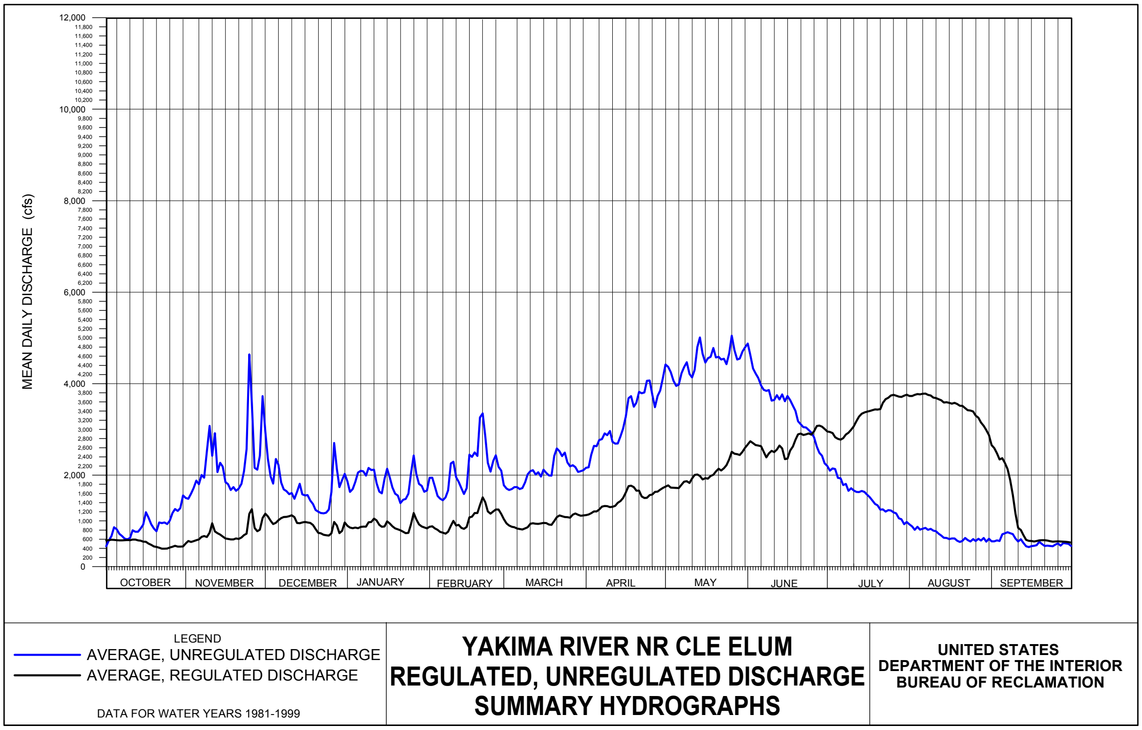
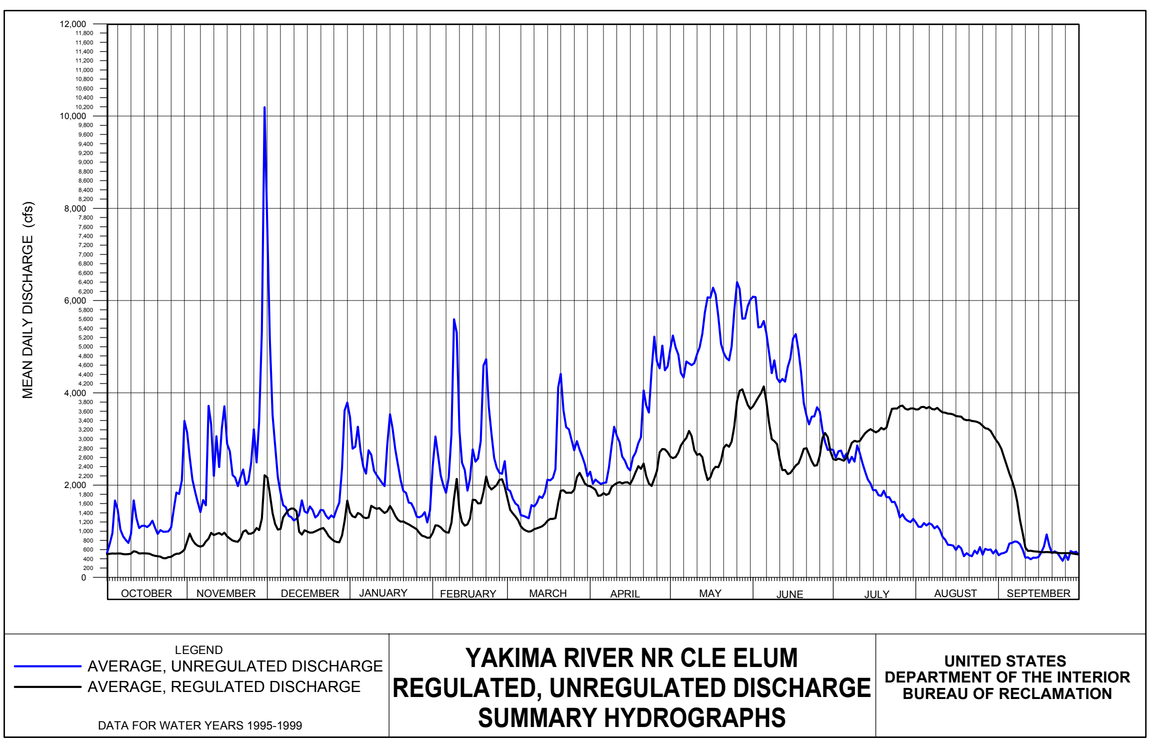
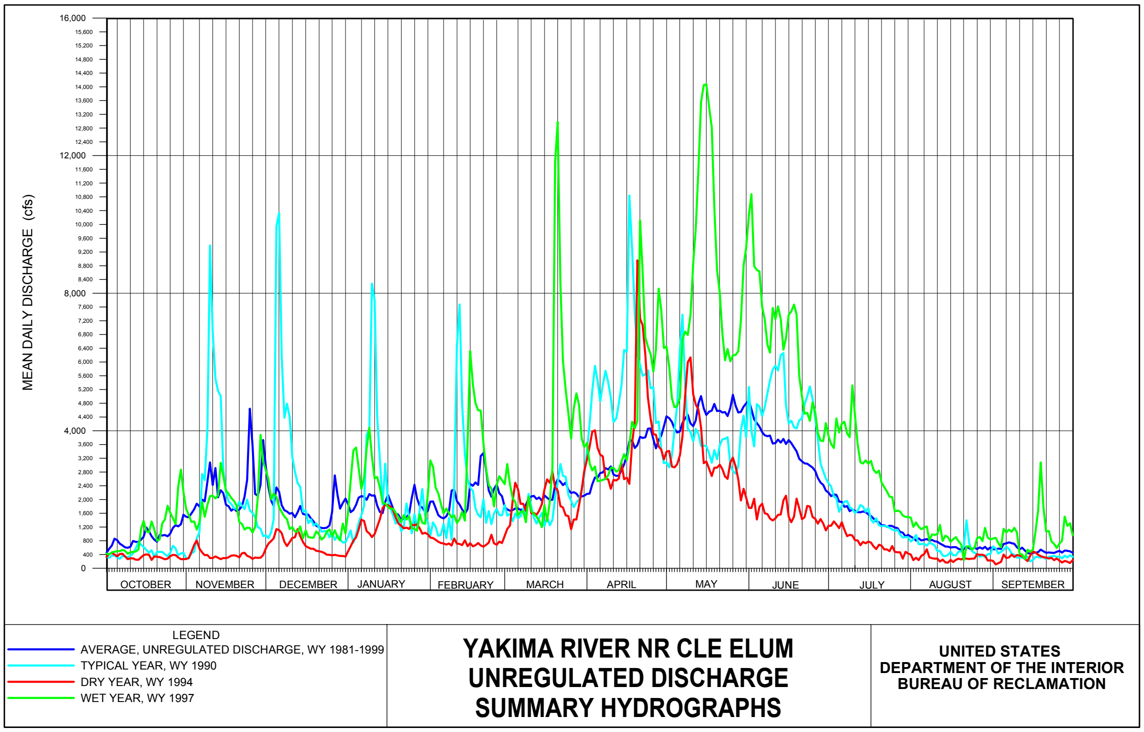
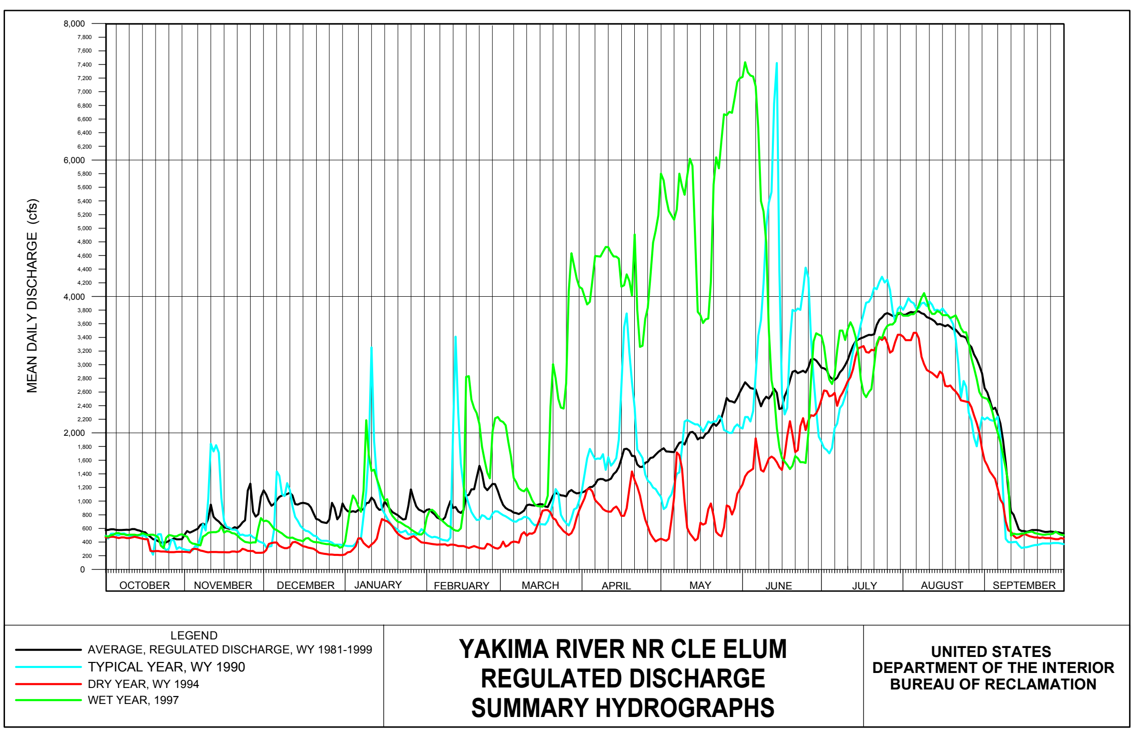
Yakima River near Cle Elum natural unregulated streamflow starts increasing mid-October through November as fall precipitation increases and evapotranspiration decreases. Natural flows will recede to winter conditions as freezing conditions in upper watersheds reduce runoff. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. Regulated streamflow is much lower than unregulated conditions and does not show the peaks due to reservoir inflows captured in storage. During the December through February period, the discharge is stable except for rain-on-snow events that formed the short duration, high discharges on a relatively infrequent basis. Regulated winter streamflow is roughly 50 percent lower than natural conditions and the frequency and magnitude of peak flows is greatly reduced due to reservoir operations for flood control and storage. In March, natural flows will increase and continue through mid-May. Unregulated streamflow forms the average annual peak discharge from April through early June. Starting in mid-April regulated streamflow shows a reduced peak as Kittitas Reclamation District (KRD) irrigation deliveries begin to increase. Current project practice for flood control operations allows for maximizing storage in late May, early June, and after this time the bypassing of reservoir natural inflows to the river system, returning some of the natural variability to the river system. Beginning early June, unregulated streamflow will decline from spring freshet to baseflow conditions by early August. Regulated flow exceeds unregulated on the average starting in late June as storage flows are wheeled to meet downstream irrigation demands. Increasing downstream demands causes the river's hydrograph to continue increasing until mid-August, then a slight decline until the start of flip-flop on September 1st. From early July until flip-flop, regulated flows are much higher (2,000 to 3,000 cfs per day) than the estimated natural unregulated flows. The estimated average natural unregulated flow from mid-August to late October is less than 600 cfs per day. From September 10th through October 20th, streamflow fluctuates very little under natural conditions, but regulated flows drop precipitously from highs in late August (3,600 cfs) to September 10th (600 cfs) after flip-flop is in place. The Yakima River near Cle Elum (YUMW) basin average annual natural flow is 1,495,088 acre-feet, of which 1,141,069 acre-feet (76%) is regulated by storage reservoirs capable of modifying the arrival time and volume of flows at the YUMW site. Yakima River near Cle Elum unregulated hydrograph is compared with a typical year, WY 1990; a dry year, 1994; and a wet year, 1997, as an indicator of the effect of climatological conditions on natural unregulated flow/discharge.

Yakima River near Cle Elum



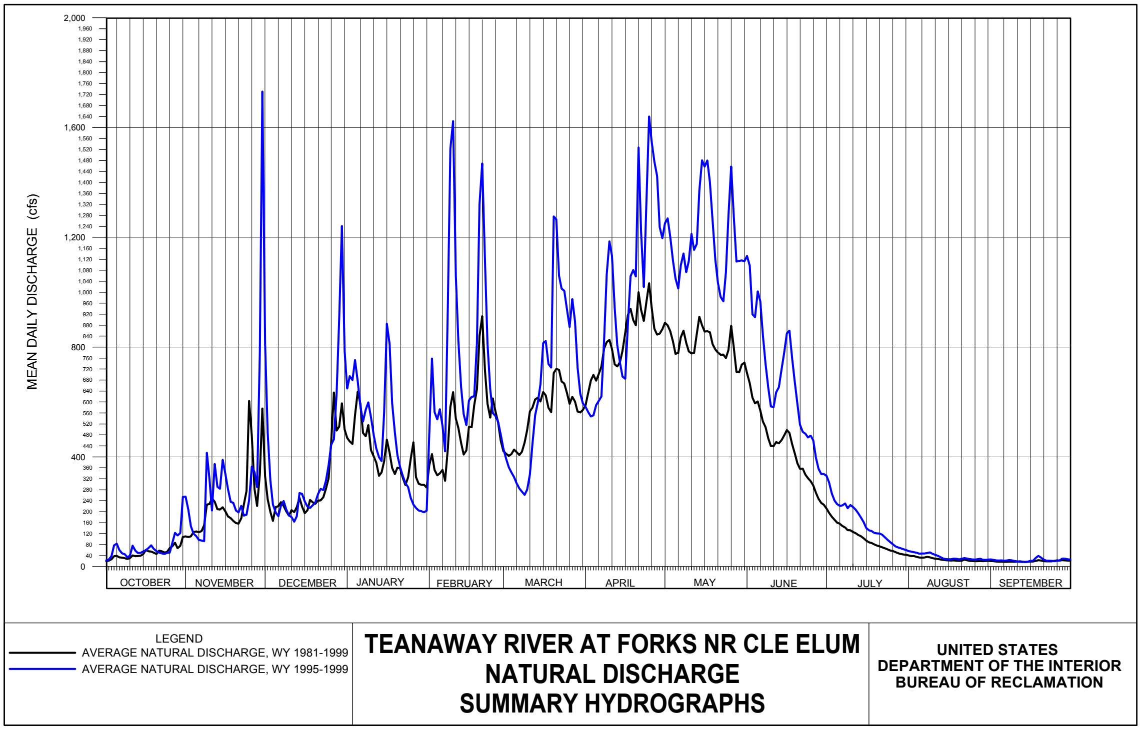


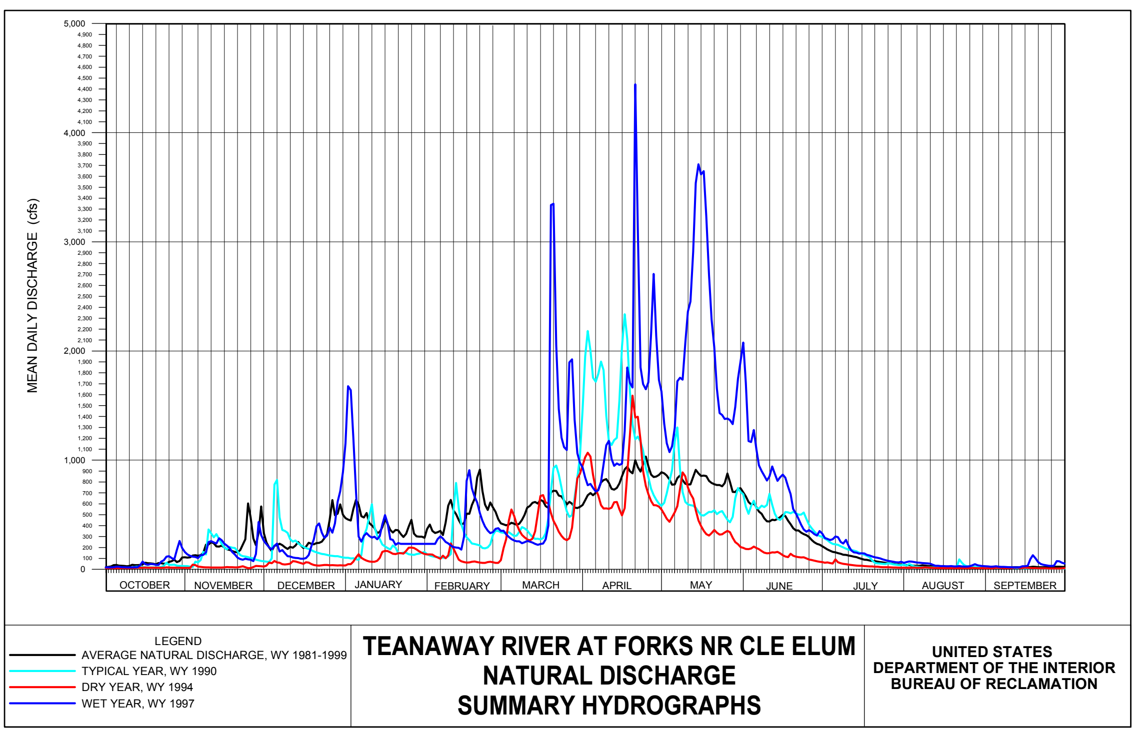

MEAN DAILY DISCHARGE (cfs)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, UNREGULATED DISCHARGE, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, WY 1997
YAKIMA RIVER NR CLE ELUM
UNREGULATED DISCHARGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


MEAN DAILY DISCHARGE (cfs)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, REGULATED DISCHARGE, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, 1997
YAKIMA RIVER NR CLE ELUM
REGULATED DISCHARGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

The Teanaway River site characterizes the unregulated runoff patterns in the upper Yakima River basin. There is little or no development or water diversions upstream from this site, but below this site from RM 9.6 to the mouth, there is significant diversion for irrigation especially during the low natural period of late July through mid-September. As in the other Yakima reservoir basins, Teanaway natural flows start increasing mid-October, continuing to increase until late November. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. December's cold weather will generally lock up the rain and snowfall causing a stabilizing effect on the outflow of the basin. In March, natural flows will increase and continue through late May or early June. Natural runoff is generally at its peak during mid-April through May period. Late June, early July, natural flow will start declining to the low period of early August through mid-October. The Teanaway basin average annual natural flow is 245,968 acre-feet, providing 134,102 acre-feet of runoff during the TWSA time period (April 1st through September 30th). The Teanaway basin only provides 10,506 acre-feet during July 1st through October 20th to meet system demands during this normal period of low natural flows.

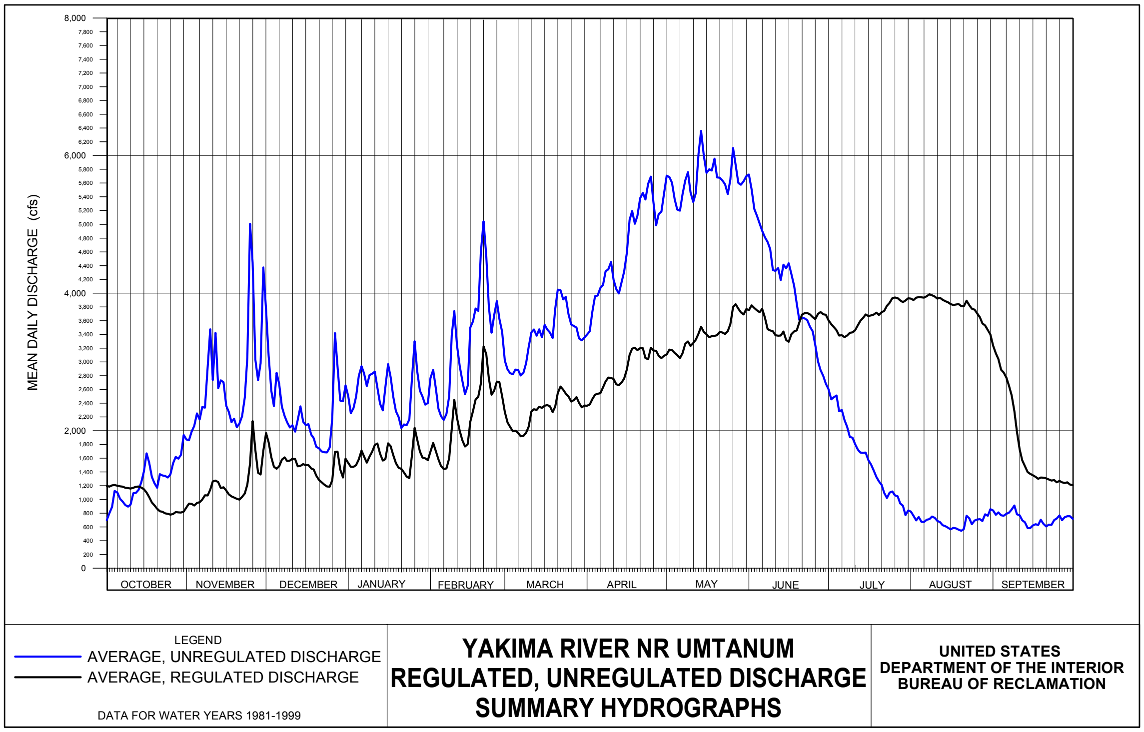
Teanaway River

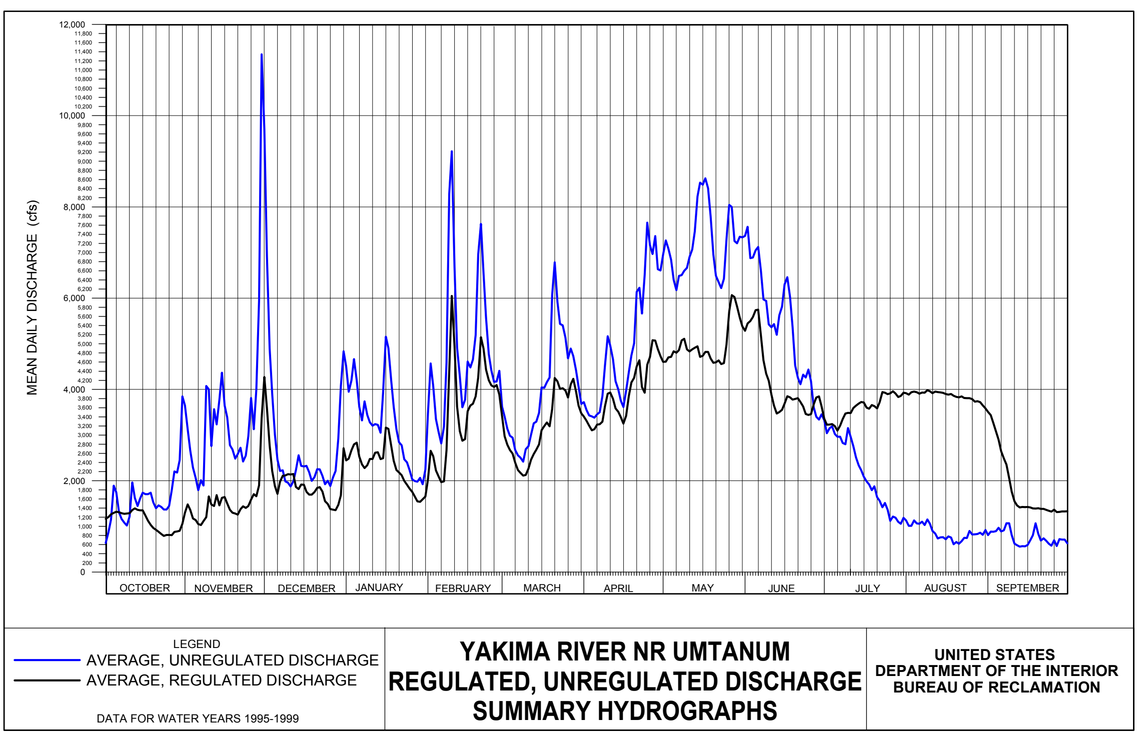


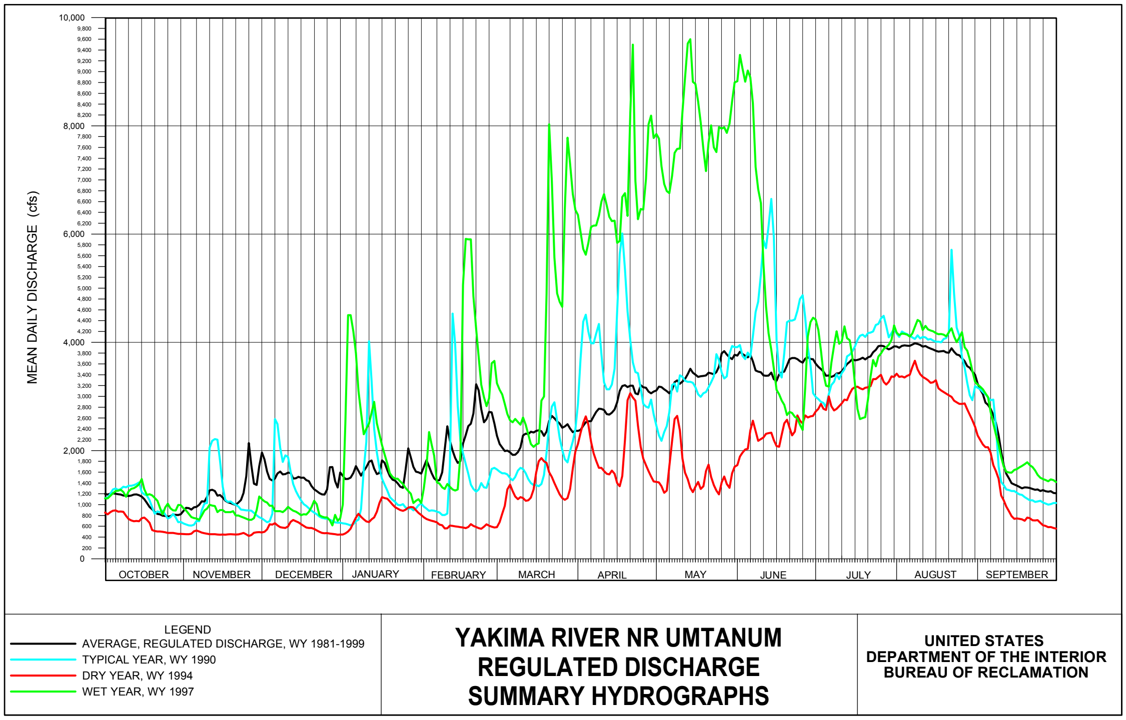


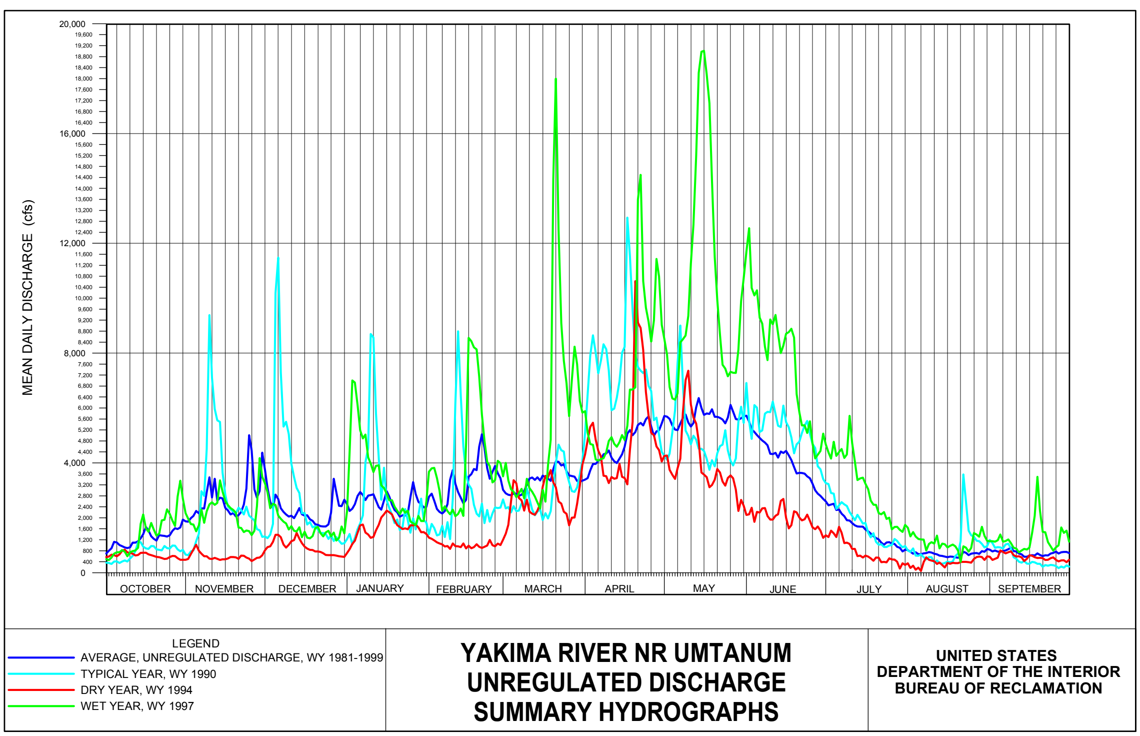
Yakima River near Umtanum natural unregulated streamflow starts increasing mid-October through November as fall precipitation increases and evapotranspiration decreases. Natural flows will recede to winter conditions as freezing conditions in upper watersheds reduce runoff. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. Regulated streamflow is below unregulated conditions and does not show the peaks due to reservoir inflows captured in storage. During the December through February period, the discharge is stable except for rain-on-snow events that formed the short duration, high discharges on a relatively infrequent basis. Regulated winter streamflow is lower than natural conditions and the frequency and magnitude of peak flows is reduced due to reservoir operations for flood control and storage. In March, natural flows will increase and continue through mid-May. Unregulated streamflow forms the average annual peak discharge from April through mid-June. From mid-April through June, regulated streamflow shows a greatly reduced peak as upper valley irrigation deliveries begin to increase. Current project practice for flood control operations allows for maximizing storage in late May, early June, and after this time the bypassing of reservoir natural inflows to the river system, returning some of the natural variability to the river system. Beginning late June, early July, unregulated streamflow will decline from spring freshet to baseflow conditions. Regulated flow exceeds unregulated on the average starting in mid-June as storage flows are wheeled to meet downstream irrigation demands. Increasing downstream demands causes the river's hydrograph to continue increasing until start of flip-flop on September 1st. From late June until flip-flop regulated flows are much higher (2,400 to 3,400 cfs per day) than the estimated natural unregulated flows. The estimated average natural unregulated flow from late July through mid-October is 700 cfs per day. From September 10th through October 20th, streamflow fluctuates very little under natural conditions, but regulated flows drop precipitously from highs in late August (4,000 cfs) to early September after flip-flop (under 1,400 cfs). The Umtanum basin average annual natural flow is 1,976,094 acre-feet, of which 1,141,069 acre-feet (58%) is regulated by storage reservoirs capable of modifying the arrival time and volume of flows at the Umtanum site. Yakima River near Umtanum unregulated hydrograph is compared with a typical year, WY 1990; a dry year, 1994; and a wet year, 1997, as an indicator of the effect of climatological conditions on natural unregulated flow/discharge.

Yakima River near Umtanum






MEAN DAILY DISCHARGE (cfs)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, REGULATED DISCHARGE, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, WY 1997
YAKIMA RIVER NR UMTANUM
REGULATED DISCHARGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


MEAN DAILY DISCHARGE (cfs)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, UNREGULATED DISCHARGE, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, WY 1997
YAKIMA RIVER NR UMTANUM
UNREGULATED DISCHARGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
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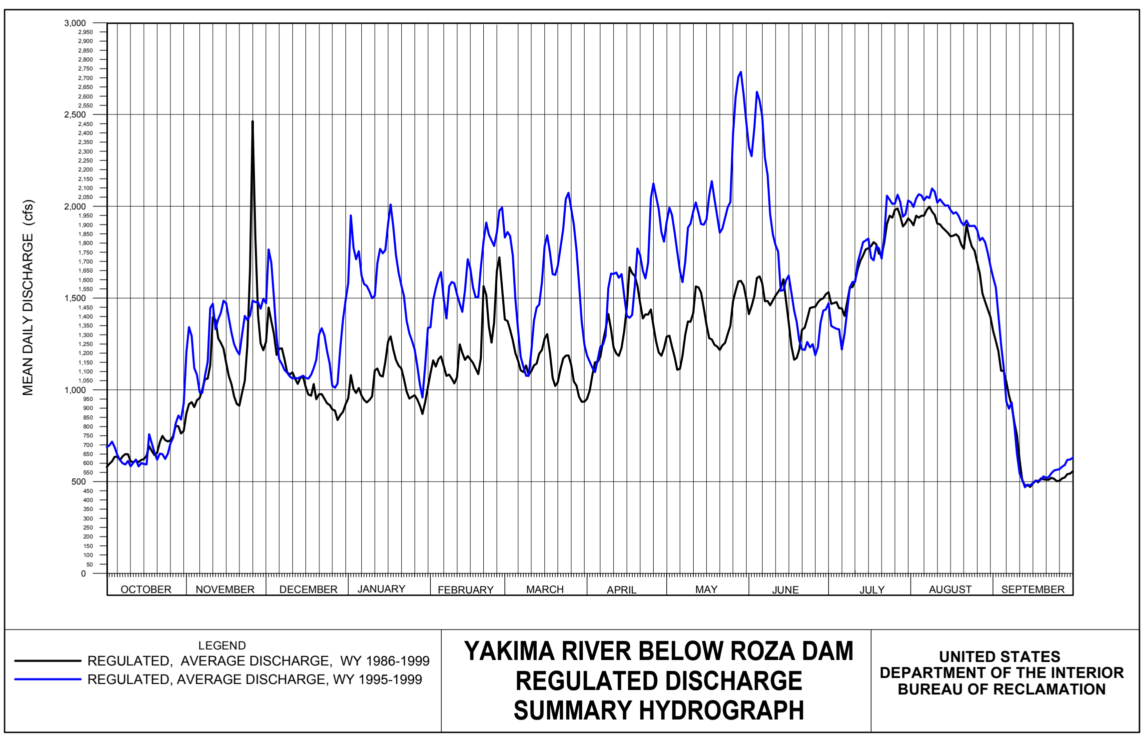
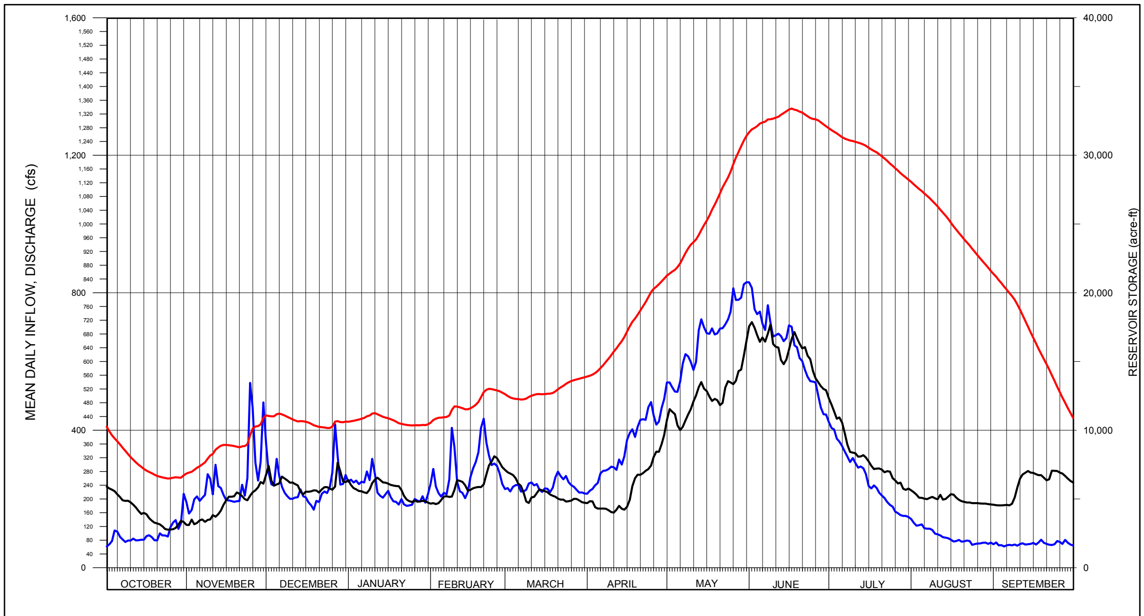
The Yakima River below Roza Dam (RBDW) regulated discharge hydrograph provides only a small clue to the relationship between unregulated and regulated flows, and provides mainly an indication of the much reduced natural variability of the hydrograph when compared to the Umtanum site located 12.5 miles upstream. Note, at this time that the stage/discharge records of RBDW are incomplete and that the site is only rated to 3,000 cfs effectively truncating all flow records greater than the rating table's 3,000 cfs. Normally RBDW hydrograph, unregulated or regulated flows matches Yakima River near Umtanum's except the volume shown is truncated or reduced due to the diversion of Roza main canal (RZCW) for irrigation and/or power production. Roza main canal's daily diversions are up to 2,200 cfs when generating power and irrigating, or up to 1,150 cfs when providing power generation only during non-irrigation season. Roza main canal's year around annual diversion is 733,478 acre-feet with a peak annual of 867,300 acre-feet during the past 19 years. Daily variability matches the upper river system, except the Roza Dam gate operation can set up hourly fluctuations which are felt all the way to the Yakima River near Parker gaging site. From September 10th through October 20th, streamflow fluctuates very little under natural conditions, but regulated flows drop precipitously from highs in late August (1,900 cfs) to early September after flip-flop (under 500 cfs).

Yakima River below Roza Dam



As in the other reservoir basins, Bumping natural inflows normally start increasing mid-October, and continuing to increase until late November when it is common to have a rain induced heavy runoff event (flood) at the end of November or early December. Cold weather will then lock up the rain and snowfall causing a very slight decline with a stabilizing effect on the inflow to the reservoir. Early April inflows will increase and continue through late May or mid-June. Late June, early July, inflow will start declining to the low period of late August and September. Natural flows are captured during the late winter and spring/summer periods for storage, targeting June 1st for maximizing storage content of the reservoir. Discharges (reservoir outflow) are made during the winter for protection of the downstream fishery resources and to provide flood control operations storage space during the November to early May period. Irrigation demands on the storage/inflow will normally begin in April and continue through September 1st when storage releases are reduced to provide downstream spawning flows that are maintainable during the winter incubation period. The comparison of natural inflow and reservoir discharge reflect a slightly lower than natural flow, but stable outflow from late October through March with almost natural variability due to flood control operations. April through June outflows tend to mirror inflow patterns, but at a reduced quantity (due to storage and flood control operations), with the inflow/outflow relationship again coming close to matching during June as storage is maximized and the natural runoff is peaking. The close comparison of inflow/outflow is due to the very high ratio (6.2 to 1) of average runoff to reservoir storage capacity. The maximum discharge releases are made during flood control operations during the November through May runoff period. Of the 205,461 acre-feet average annual natural (unregulated) flow generated in the Bumping basin, only 53,437 acre-feet (26%) is delivered/released during July 1st through October 20th to meet system demands during this normal period of low natural flows. During the July 1st through October 20th period, only 24,945 acre-feet of this delivery is from the storage component of the water supply.

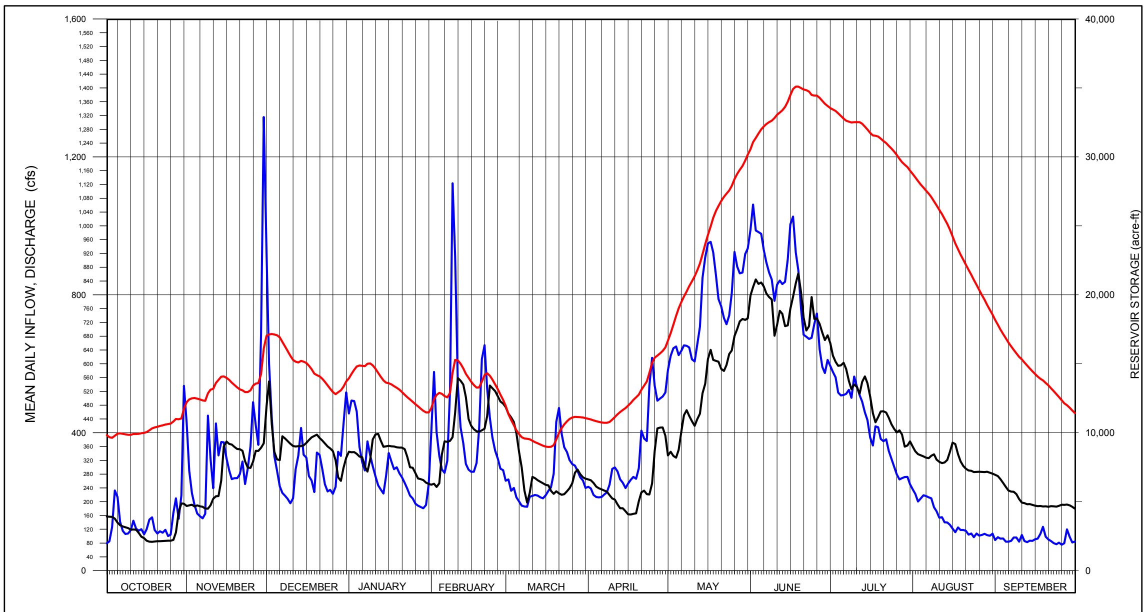
Bumping



LEGEND
AVERAGE, MEAN DAILY INFLOW
AVERAGE, MEAN DAILY DISCHARGE
AVERAGE RESERVOIR STORAGE
DATA FOR WATER YEARS 1981-1999

BUMPING RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION



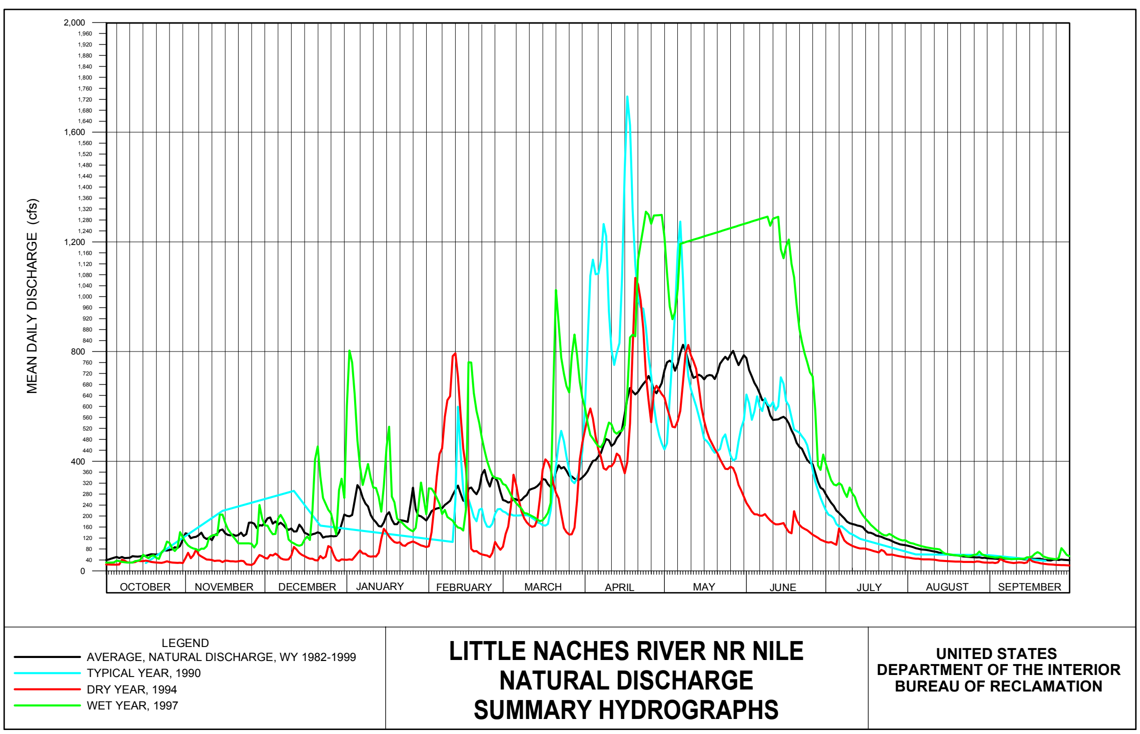
LEGEND
AVERAGE, MEAN DAILY INFLOW
AVERAGE, MEAN DAILY DISCHARGE
AVERAGE, RESERVOIR STORAGE
DATA FOR WATER YEARS 1995-1999

BUMPING RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

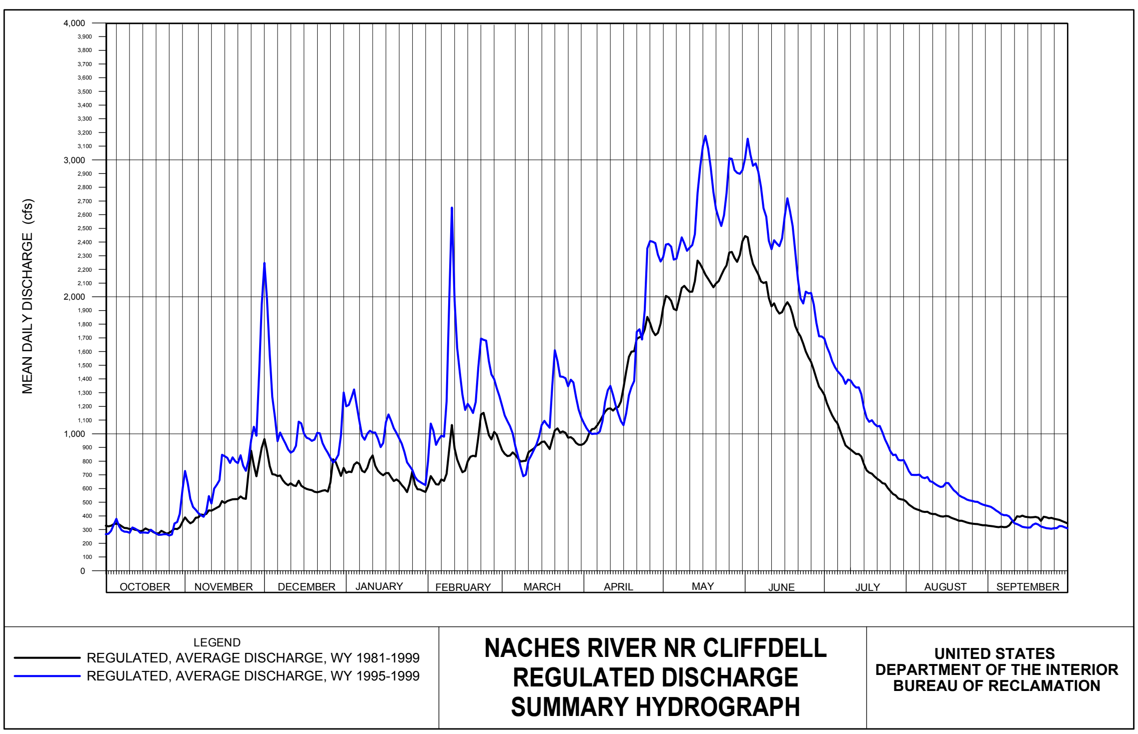
The Little Naches River site characterizes the unregulated runoff patterns in the Naches River basin. There is no development or water diversions upstream from this site. As in the other Yakima reservoir basins, Little Naches natural flows start increasing mid-October and continue through late November. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. December's cold weather will then lock up the rain and snowfall causing a stabilizing effect on the outflow of the basin. In March, natural flows start to increase and continue through late May or early June. Natural runoff is generally at its peak during mid-April through early June period. Late June, early July, natural flow will start declining to the low period of mid-August through mid-October. The Little Naches basin average annual natural flow is 181,895 acre-feet, providing 113,832 acre-feet of runoff during the TWSA time period (April 1st through September 30th). The Little Naches basin only provides 17,069 acre-feet during July 1st through October 20th to meet system demands during this normal period of low natural flows.

Little Naches River



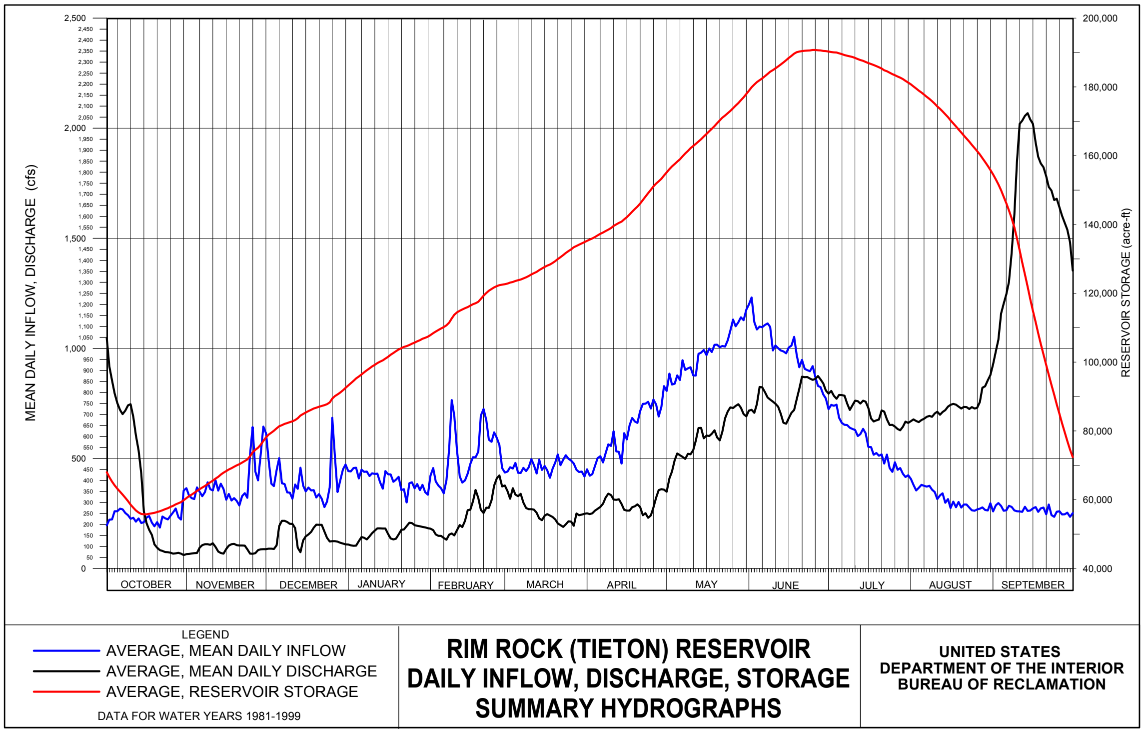
The Naches River near Cliffdell represents a river site with some development in its watershed, but not enough to completely change the natural streamflow regime. With the construction of Bumping Lake Reservoir, only 70.7 mi.^{2} (17.9%) of the Cliffdell's 394 mi.^{2} watershed came under a regulating influence, but with Bumping's average runoff to storage capacity ratio 6.2 to 1 the effect on Cliffdell's natural flow volume and variability was minimal. As in the other Yakima basins, Naches River near Cliffdell natural flows/discharges start increasing mid-October, continuing to increase until late November. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. December's cold weather will then lock up the rain and snowfall causing a slight decline in discharge and a stabilizing effect on the outflow of the basin. In March, natural flows will start to increase and continue through late May, early June. Natural runoff is generally at its peak during mid-April through early June period. Late June, early July, natural flow will start declining to the low period of mid-August through mid-October. Flood control space releases at Bumping have a small impact upon Cliffdell's discharges. Bumping storage releases for irrigation during the late July through August period support a higher discharge than natural flow regime for this site and continues doing so with incubation protect releases during the winter months, until flood control space release are made.

Naches River near Cliffdell



Normally, as in the other Yakima reservoir basins, Rimrock natural inflows start increasing mid-October, continuing to increase until late November. It is common to have a rain induced flood event at the end of November or early December. Cold weather will then lock up the rain and snowfall causing a slight decline and stabilizing effect on the inflow to the reservoir. In late March, inflows will start to increase and continue through late May or June. Late June, early July, inflow will start declining to the low period of late August and September. Natural flows are captured during the winter and spring/summer periods for storage, targeting June 1st for maximizing storage content of the reservoir. Discharges (reservoir outflow) are made during the winter for protection of the downstream fishery resources and to provide flood control operations storage space during the November to early May period. Moderate irrigation demands on the storage/inflow will normally begin in early April and continue through late August. Beginning September 1st (start of flip-flop) storage releases are increased four-fold to compensate for the reduction of the upper Yakima River flows, and Rimrock outflows become the primary source of irrigation water supply for the Yakima basin below Roza Dam until October 20th (end of irrigation season). The comparison of natural inflow and reservoir discharge reflect a greatly lower (less than 20%) than natural flow, but stable outflow during late October and November; with December through March still reflecting a lower outflow (less than 35%) than natural, but with more variability due to flood control operations. Mid-April through June outflows tend to mirror inflow patterns, but at a reduced quantity (due to storage and flood control operations), with the inflow/outflow relationship coming closest to matching during June as storage is maximized and the natural runoff is peaking. Currently, the maximum discharge releases (2,200 to 2,600 cfs) are made during September 10th through September 30th for irrigation demands. Of the 369,323 acre-feet average annual natural (unregulated) flow generated in the Rimrock basin, 209,373 acre-feet (57%) is delivered/released during July 1st through October 20th to meet system demands during the normal period of low natural flows. During the July 1st through October 20th period, 131,083 acre-feet of this delivery is from the storage component of the water supply. Rimrock (Tieton) Reservoir unregulated and regulated hydrographs are compared with a typical year, WY 1990; a dry year, 1994; and a wet year, 1997, as an indicator of the effect of climatological conditions on natural unregulated and regulated flow/discharge.

Rimrock



MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, MEAN DAILY INFLOW
AVERAGE, MEAN DAILY DISCHARGE
AVERAGE, RESERVOIR STORAGE
DATA FOR WATER YEARS 1981-1999
RIM ROCK (TIETON) RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
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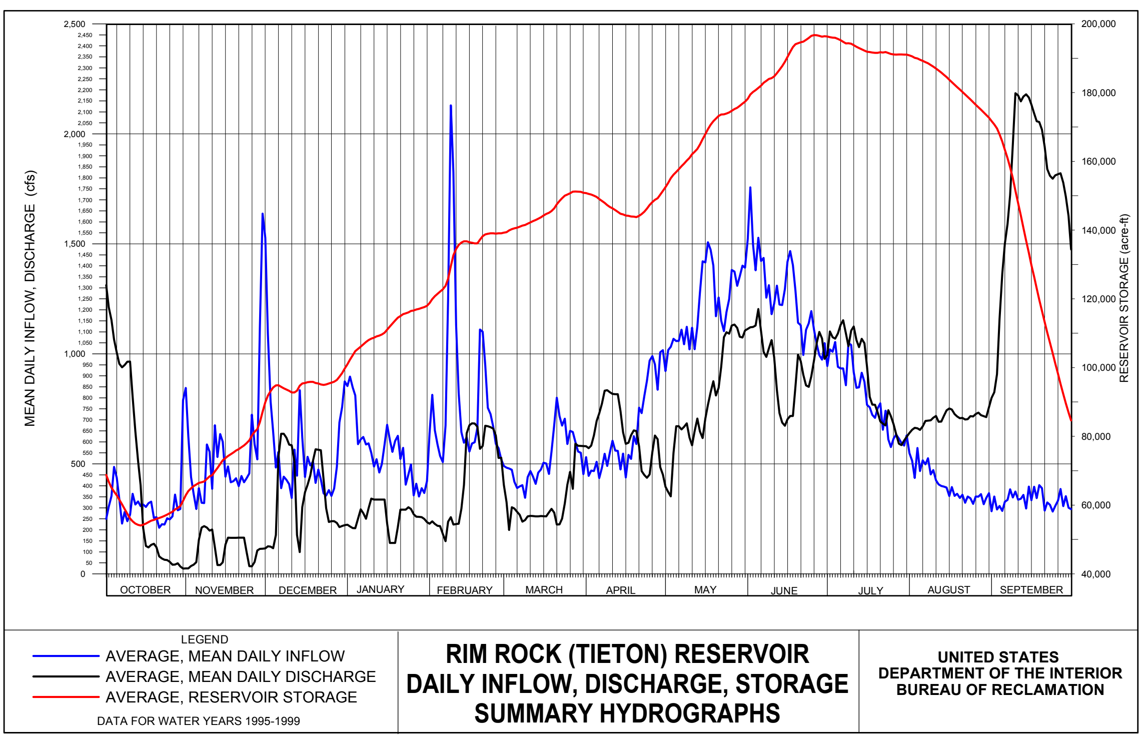
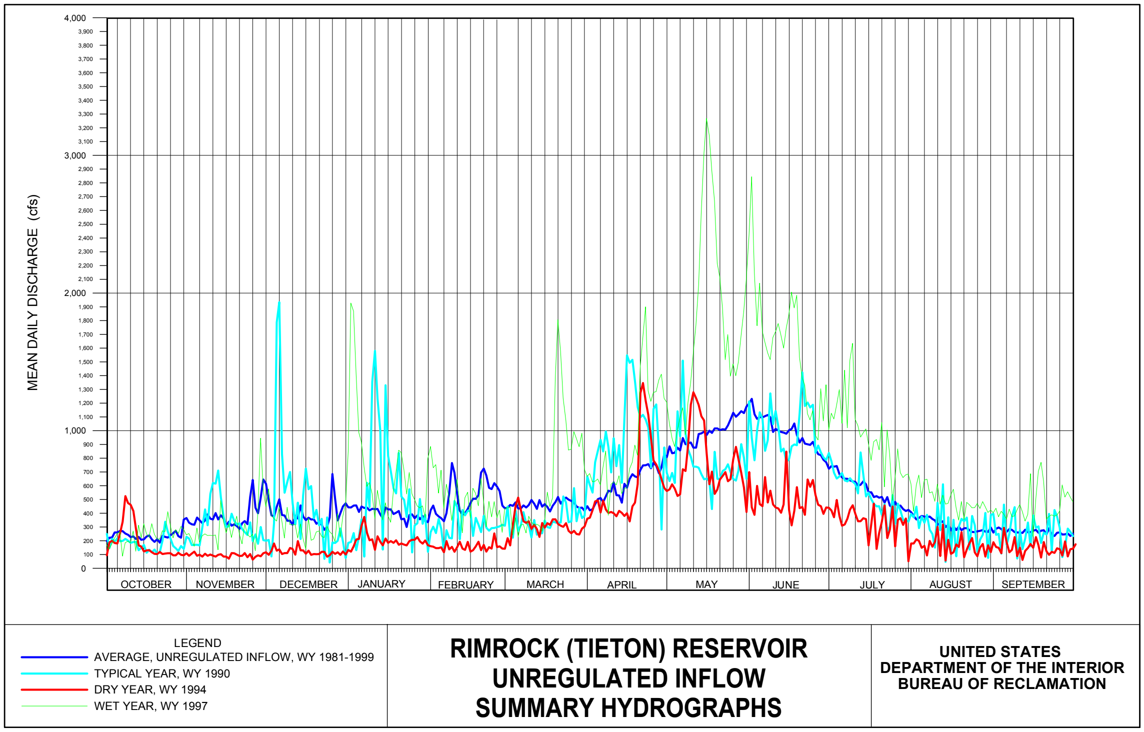
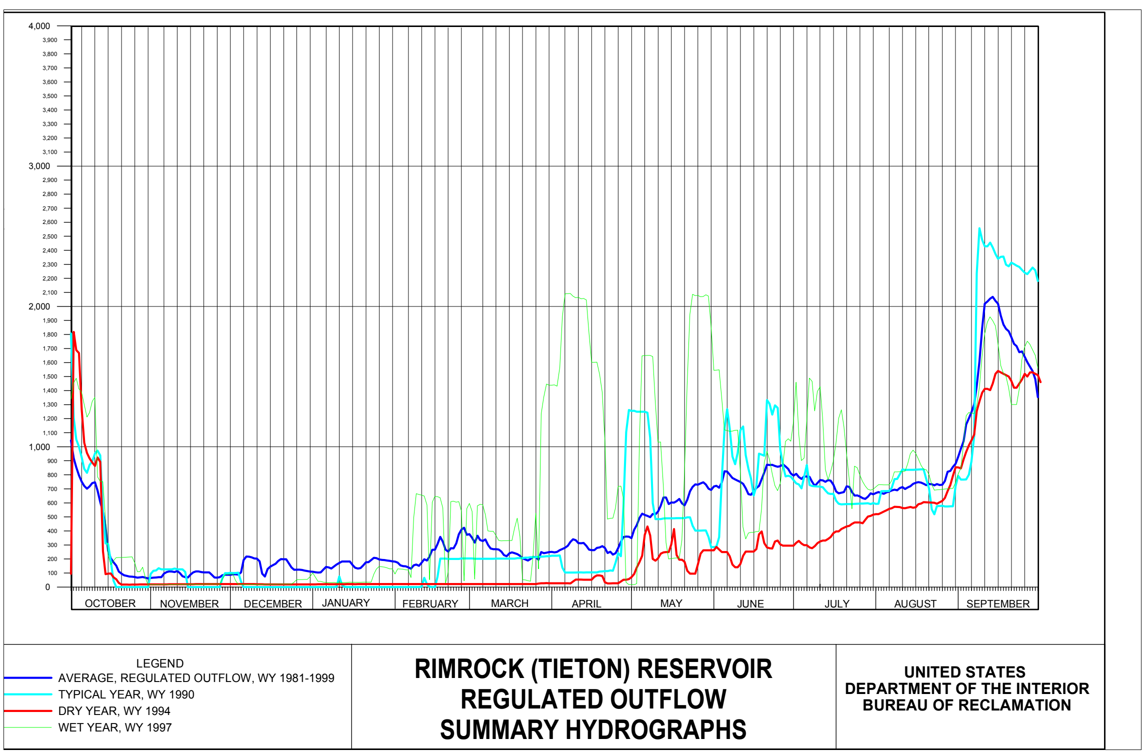
BUREAU OF RECLAMATION



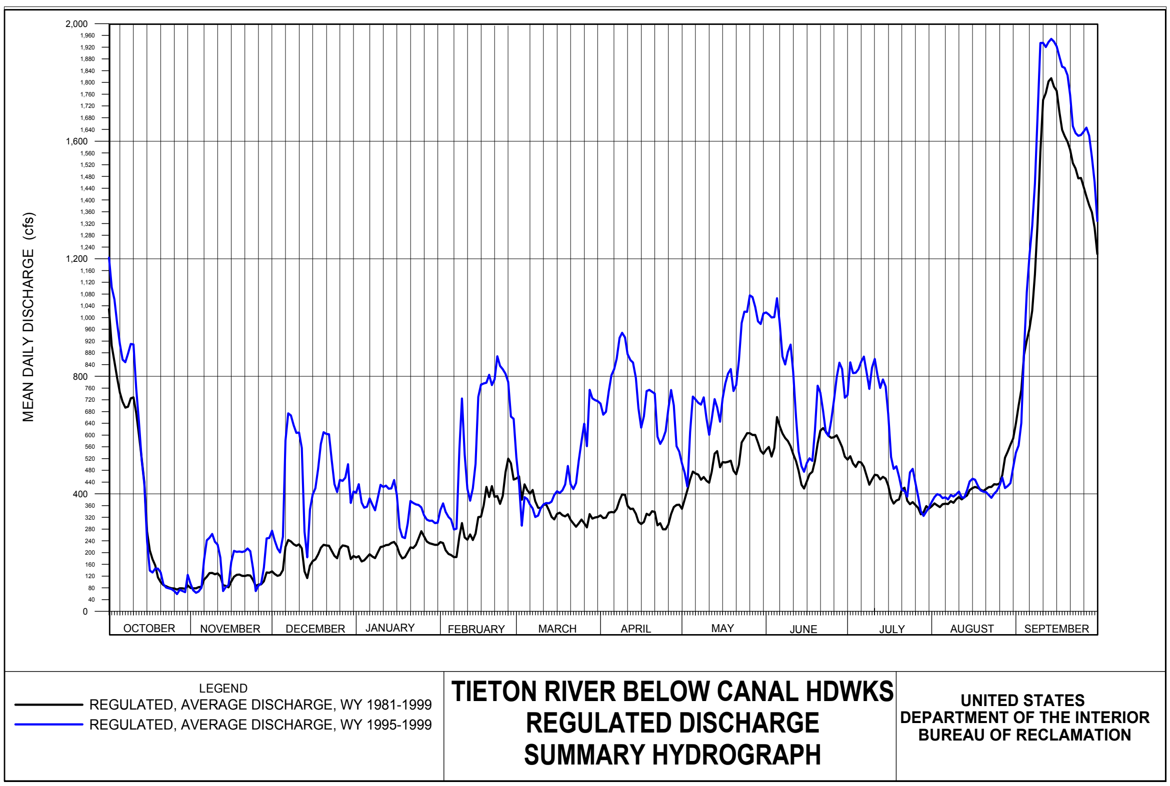
MEAN DAILY INFLOW, DISCHARGE (cfs)
RESERVOIR STORAGE (acre-ft)
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, MEAN DAILY INFLOW
AVERAGE, MEAN DAILY DISCHARGE
AVERAGE, RESERVOIR STORAGE
DATA FOR WATER YEARS 1995-1999
RIM ROCK (TIETON) RESERVOIR
DAILY INFLOW, DISCHARGE, STORAGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


MEAN DAILY DISCHARGE (cfs)
4,000
3,000
2,000
1,000
0
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, UNREGULATED INFLOW, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, WY 1997
RIMROCK (TIETON) RESERVOIR
UNREGULATED INFLOW
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


4,000
3,000
2,000
1,000
0
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, REGULATED OUTFLOW, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, WY 1997
RIMROCK (TIETON) RESERVOIR
REGULATED OUTFLOW
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

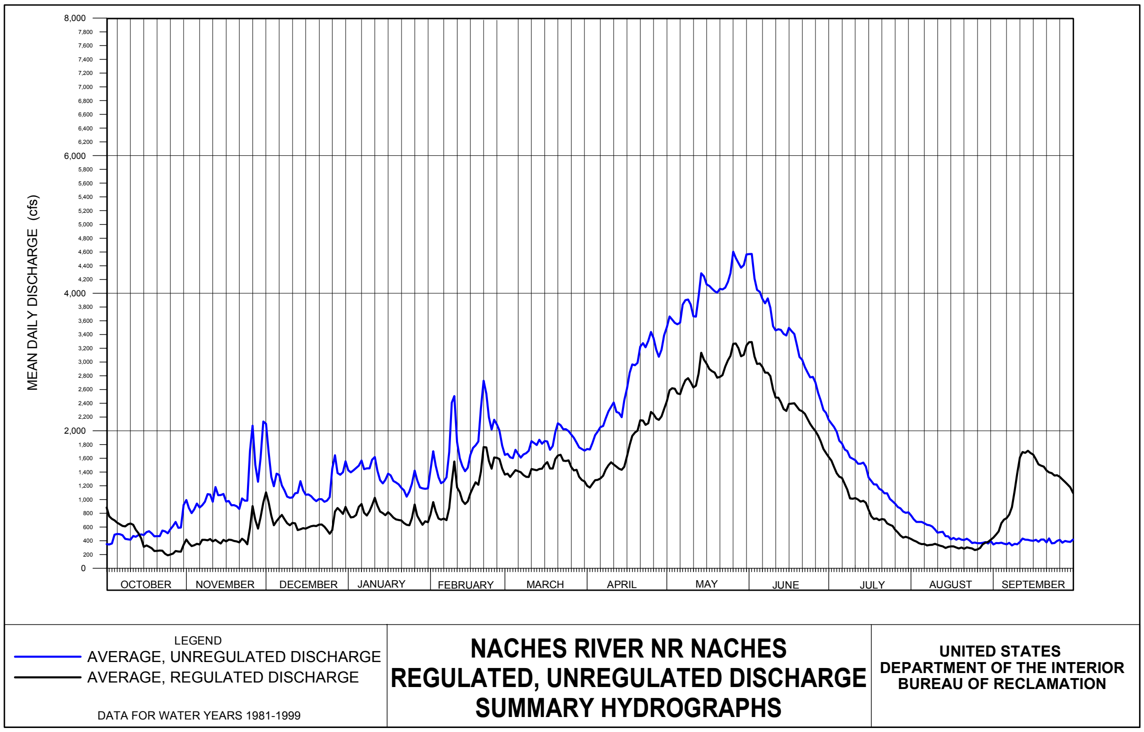
Normally, Tieton River below Canal Headworks (TICW) hydrograph, unregulated or regulated flows, closely matches Rimrock located 7.2 miles upstream, except the volume shown is reduced due to the diversion of Yakima-Tieton Canal (TIEW) for irrigation from late March through early October. Some local unregulated variability is developed by inflows to the reach below Rimrock, such as produced by Wildcat Creek. TIEW daily diversions are up to 330 cfs when irrigating with average annual diversion of 83,923 acre-feet with a peak annual of 98,852 acre-feet during the past 19 years. From September 1st through October 20th, streamflow fluctuates very little under natural conditions, but regulated flows rise precipitously from lows in late August (400 cfs) to September 10th (1,950 cfs) after flip-flop is in-place, and then starting to slowly decline to late October's 80 cfs due to reduced irrigation demands.

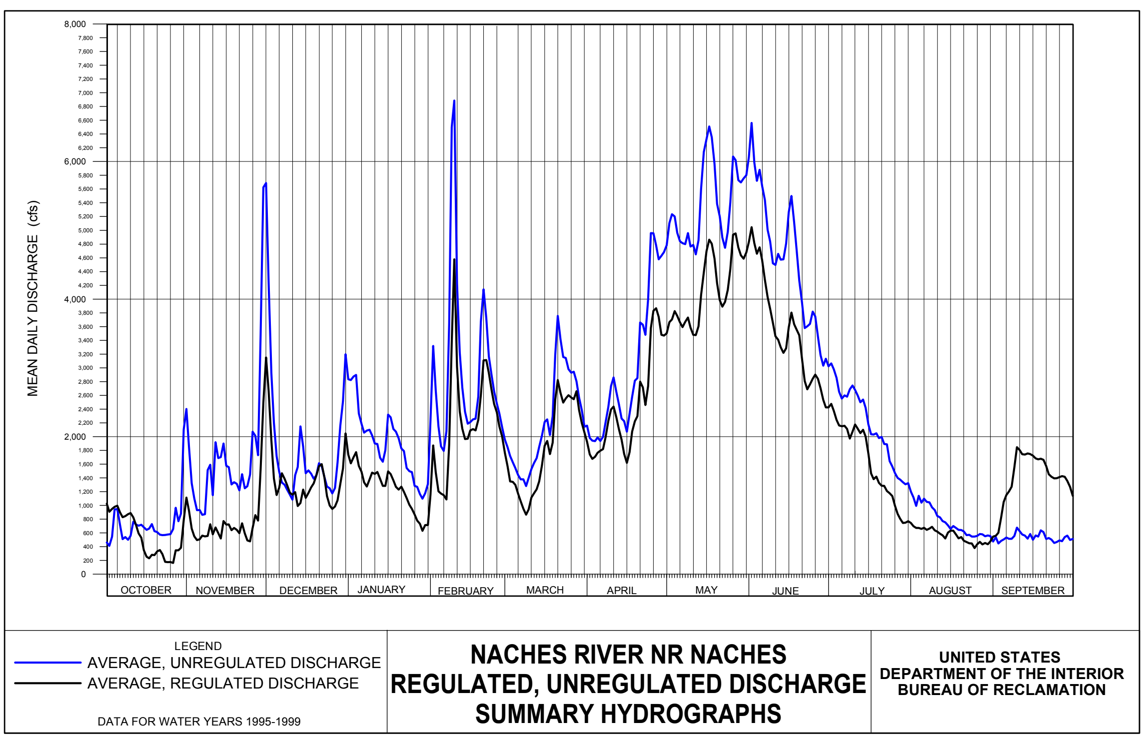
Tieton River below Canal Headworks

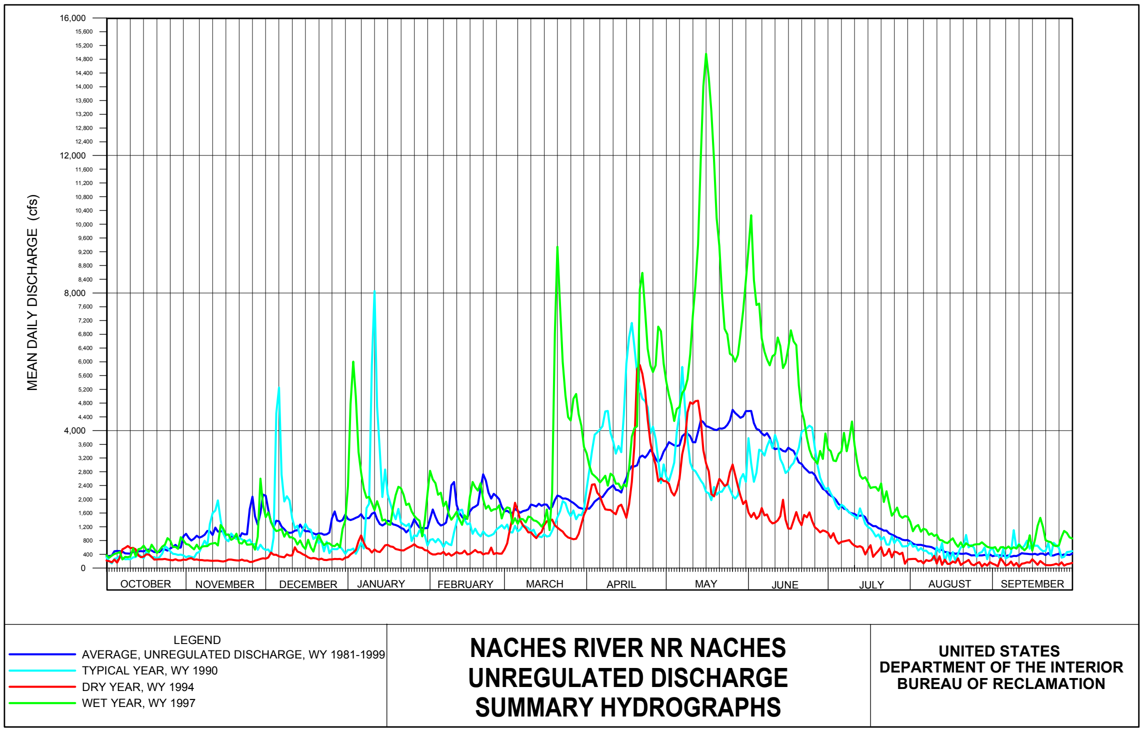


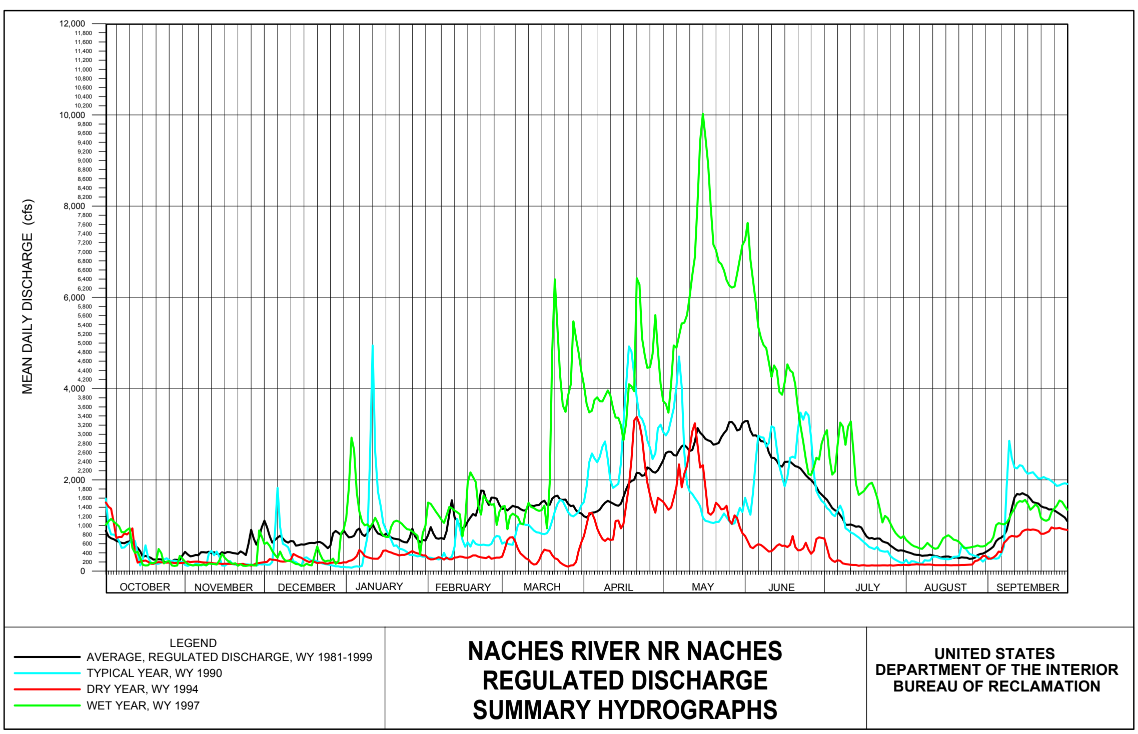
Naches River near Naches (NACW) natural unregulated streamflow starts increasing slowly, mid-October through November as fall precipitation increases and then natural flows will recede to winter conditions as freezing conditions in upper watersheds reduce runoff. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. Regulated streamflow is much lower than unregulated conditions and does not show the peaks due to reservoir inflows captured in storage. During the December through February period, the discharge is stable except for rain-on-snow events that formed the short duration, high discharges on a relatively infrequent basis. Regulated winter streamflow is roughly 43 percent lower than natural conditions, and the frequency and magnitude of peak flows is greatly reduced due to reservoir operations for flood control and storage. In March, natural flows will start to increase and continue through late May. Unregulated streamflow forms the average annual peak discharge from April through early June. Starting in April, regulated streamflow is very slightly reduced as irrigation deliveries above NACW begin to increase. Current project practice for flood control operations allows for maximizing storage in late May, early June, and after this time the bypassing of reservoir natural inflows to the river system, returning some of the natural variability to the river system. Beginning mid-June, unregulated streamflow will decline from spring freshet to baseflow conditions by late August. Based on the past 19 years, regulated flow only exceeds unregulated from the start of flip-flop in late August to the end of the irrigation season October 20th, flows are wheeled to meet downstream irrigation demands that were earlier supported from the upper Yakima reach. From early July until late August or start of flip-flop, regulated flows are lower (200 to 600 cfs per day) than the estimated natural unregulated flows. The estimated average natural unregulated flow from mid-August to late October is less than 425 cfs per day. From September 10th through October 20th, streamflow fluctuates very little under natural conditions, but regulated flows rise precipitously from lows in late August (300 cfs or less) to September 10th (1,900 cfs) after flip-flop is in place. At some time, in most years, NACW regulated flows will drop to 125 cfs or lower (80 cfs) due in part to the Wapatox Power Canal year around non-consumptive natural flow right diversion of 300 to 450 cfs. The NACW basin average annual natural flow is 1,199,029 acre-feet, of which 574,784 acre-feet (48%) is regulated by storage reservoirs capable of modifying timing and volume of flows at the NACW site, but at a reduced magnitude when compared to the upper Yakima River reach. The NACW unregulated and regulated hydrographs are compared with a typical year, WY 1990; a dry year, 1994; and a wet year, 1997, as an indicator of the effect of climatological conditions on natural unregulated and regulated flow/discharge.

Naches River near Naches



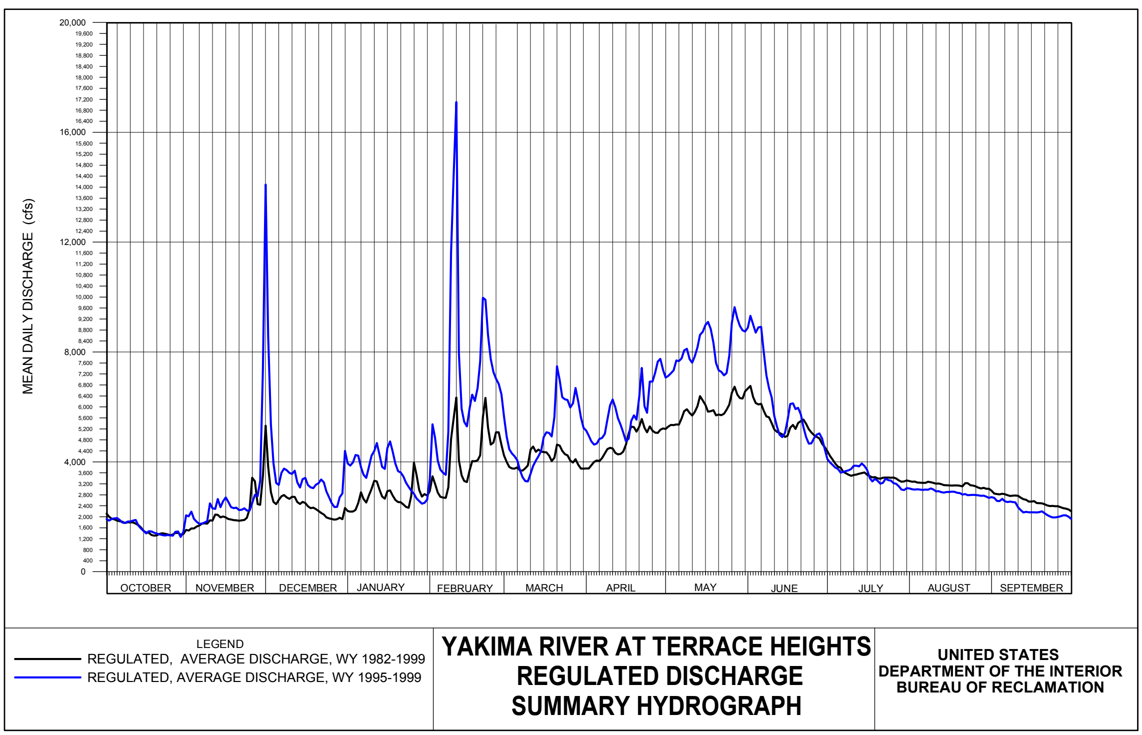



MEAN DAILY DISCHARGE (cfs)
16,000
12,000
8,000
4,000
0
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, UNREGULATED DISCHARGE, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, WY 1997
NACHES RIVER NR NACHES
UNREGULATED DISCHARGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


MEAN DAILY DISCHARGE (cfs)
12,000
10,000
8,000
6,000
4,000
2,000
0
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
LEGEND
AVERAGE, REGULATED DISCHARGE, WY 1981-1999
TYPICAL YEAR, WY 1990
DRY YEAR, WY 1994
WET YEAR, WY 1997
NACHES RIVER NR NACHES
REGULATED DISCHARGE
SUMMARY HYDROGRAPHS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

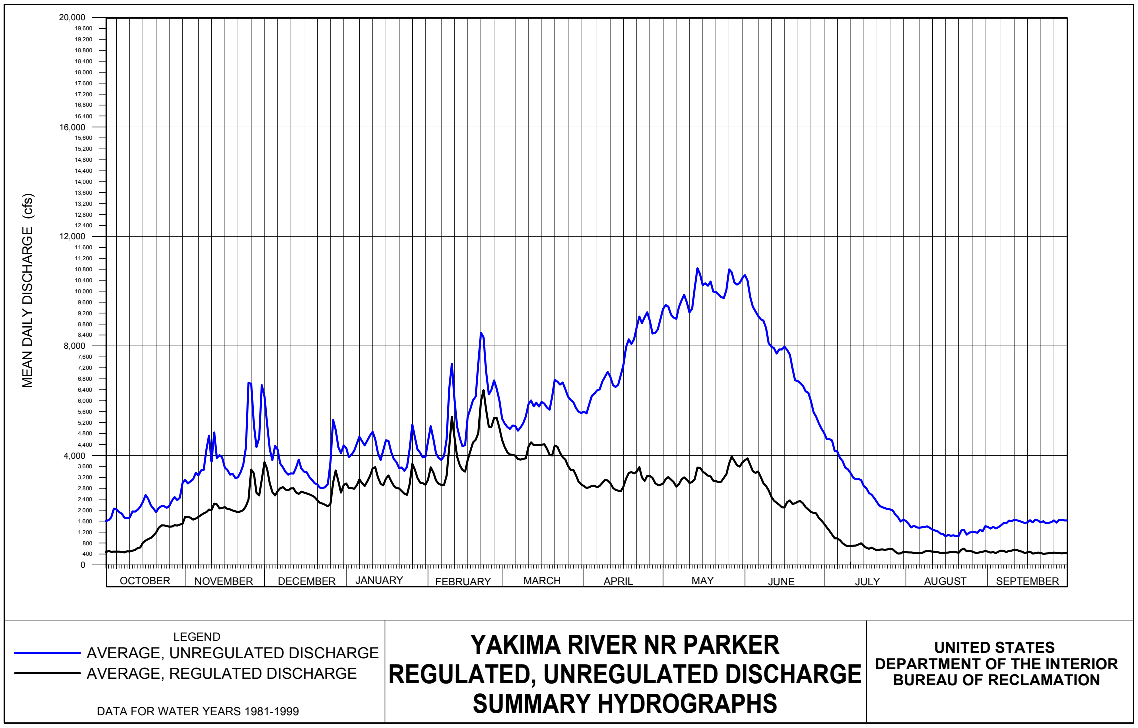
The Yakima River at Terrace Heights (YRTW) regulated discharge hydrograph provides the relationship between unregulated and regulated flows when compared to the Yakima River near the Parker (PARW) site located 9.5 miles downstream. The comparison between these two sites is valid because there is only a small percentage of PARW unregulated flow coming into the reach from Ahtanum and Wide Hollow Creeks below YRTW. YRTW is also the first gage site below the confluence of the Naches River with the Yakima River. The YRTW discharges provide an indication of the variability of the regulated hydrograph, but stage/discharge records of YRTW are provisional and may not provide an accurate representation of volume discharge. Normally, if available, YRTW unregulated flows would match PARW's unregulated hydrograph except being slightly reduced due to Ahtanum and Wide Hollow Creeks' inflows. YRTW regulated hydrograph flows come close to representing the daily variability of the combined upper Yakima River and Naches River systems, and minus irrigation diversions of up to 3,300 cfs, should closely match PARW's hydrograph. During late July until mid-October, streamflow fluctuates very little under natural conditions, but regulation of storage for irrigation demands and operating for Yakima River Basin Water Enhancement Project (YRBWEP) targets, maintains fairly constant daily flows at YRTW, and normally no perceivable change to YRTW flows from the flip-flop operation. From late July until late September, regulated flows are much higher (up to 2,000 to 2,400 cfs per day) than the estimated natural unregulated flows.

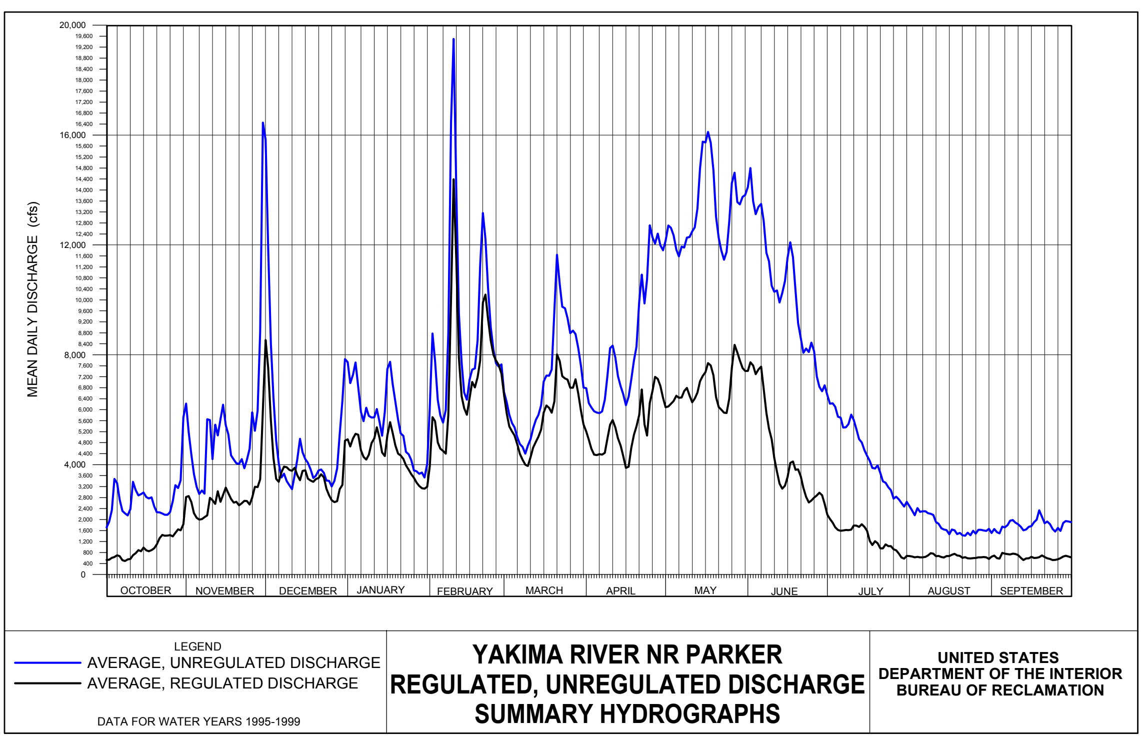
Yakima River @ Terrace Heights

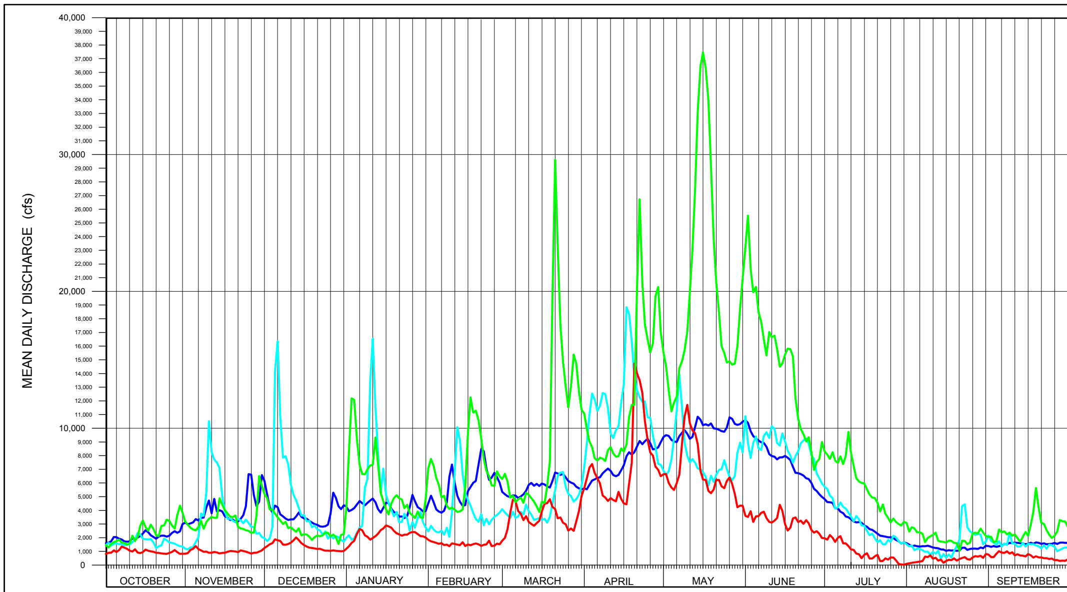


Yakima River near Parker (PARW) natural unregulated streamflow starts increasing mid-October through November as fall precipitation increases and evapotranspiration decreases. Natural flows will recede to winter conditions as freezing conditions in upper watersheds reduce runoff. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. Regulated streamflow is much lower than unregulated conditions and does not show the peaks due to reservoir inflows captured in storage. During the December through February period the discharge is relatively stable except for rain-on-snow events that formed the short duration, high discharges on an infrequent basis. Regulated winter (late December through February) streamflow is roughly 34 percent lower than natural conditions, and the frequency and magnitude of peak flows is greatly reduced due to reservoir operations for flood control and storage. In March, natural flows increase and continue through late May. Unregulated streamflow forms the average annual peak volume discharge period from April through early June. Starting in late March, regulated streamflow is reduced as irrigation deliveries above PARW begin to increase. Current project practice for flood control operations allows for maximizing storage in late May, early June, and after this time the bypassing of reservoir natural inflows to the river system, returning some of the natural variability to the river system. Beginning mid-June, unregulated streamflow will decline from spring freshet to baseflow conditions by early August. Based on the past 19 years, regulated flow never exceeds unregulated natural flow during the entire water year, even during the low natural flow period July 1st through October 20th, when peak storage is wheeled to meet TWSA irrigation demands. Note: up to 3,330 cfs is diverted at Sunnyside Valley Irrigation District (SVID) and Wapato Irrigation Project (WIP), both of which are located just upstream of the PARW gaging station. PARW is the controlling site for calculation of TWSA, which also is used to establish YRBWEP target flows for PARW and YRPW from April through October. These YRBWEP target flows (300, 400, 500, or 600 cfs based on TWSA) set the minimum instream regulated flow for this period of time. From late July until mid-October, regulated flows are lower (900 to 1,200 cfs per day) than the estimated natural unregulated flows. The estimated average natural unregulated flow from mid-August to early October is less than 1,300 cfs per day and in a dry water year this unregulated flow may approach zero. During late July until mid-October, streamflow fluctuates very little under natural conditions, but regulation of storage demands and operating for YRBWEP targets maintains fairly constant daily flows at PARW, and normally no perceivable change to PARW flows from the flip-flop operation. When the system is on storage control it is possible, due to operation of diversion faculties, to develop hourly cyclic fluctuations at PARW site. The PARW basin average annual natural flow is 3,390,551 acre-feet, of which 1,713,282 acre-feet (51%) is regulated by storage reservoirs, delaying and modifying discharge timing and volume rate of flows by as much as 112 days at the PARW site. Recognized TWSA plus post-1905 rights irrigation diverters require diversion of 52 percent of the total annual natural flow during the April through October irrigation season, and a total average annual diversion of 2,093,100 acre-feet during this same time period. Yakima River near Parker unregulated and regulated hydrographs are compared with a typical year, WY 1990; a dry year, 1994; and a wet year, 1997, as an indicator of the effect of climatological conditions on natural unregulated and regulated flow/discharge.

Yakima River near Parker – TWSA Control Site







LEGEND
- AVERAGE, UNREGULATED DISCHARGE, WY 1981-1999
- TYPICAL YEAR, WY 1990
- DRY YEAR, WY 1994
- WET YEAR, WY 1997

YAKIMA RIVER NR PARKER
UNREGULATED DISCHARGE
SUMMARY HYDROGRAPHS

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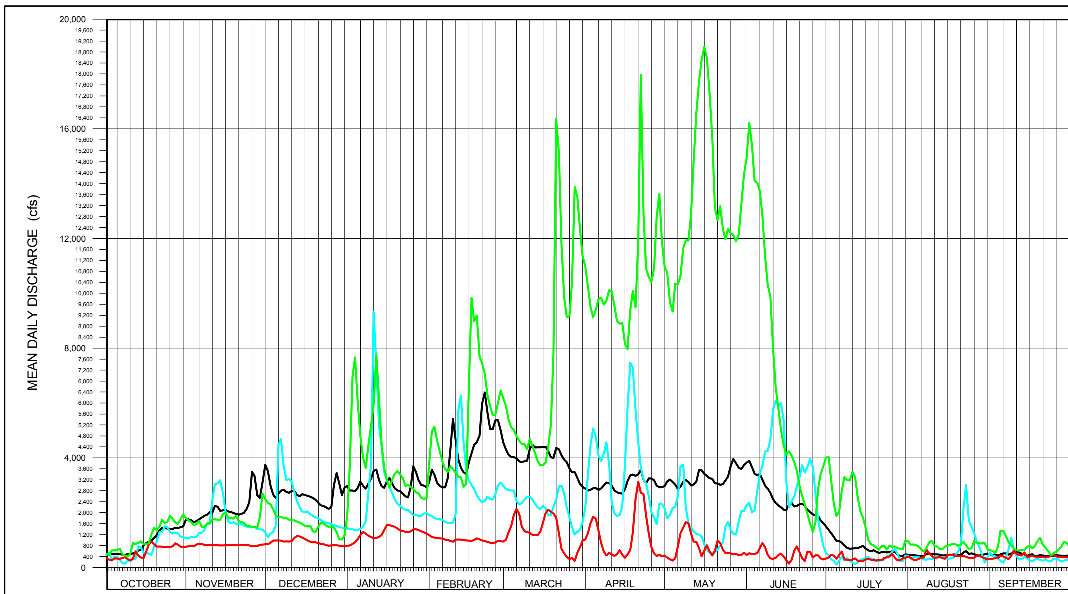

LEGEND
- AVERAGE, REGULATED DISCHARGE, WY 1981-1999
- TYPICAL YEAR, WY 1990
- DRY YEAR, WY 1994
- WET YEAR, WY 1997

YAKIMA RIVER NR PARKER
REGULATED DISCHARGE
SUMMARY HYDROGRAPHS

UNITED STATES
DEPARTMENT OF THE INTERIOR
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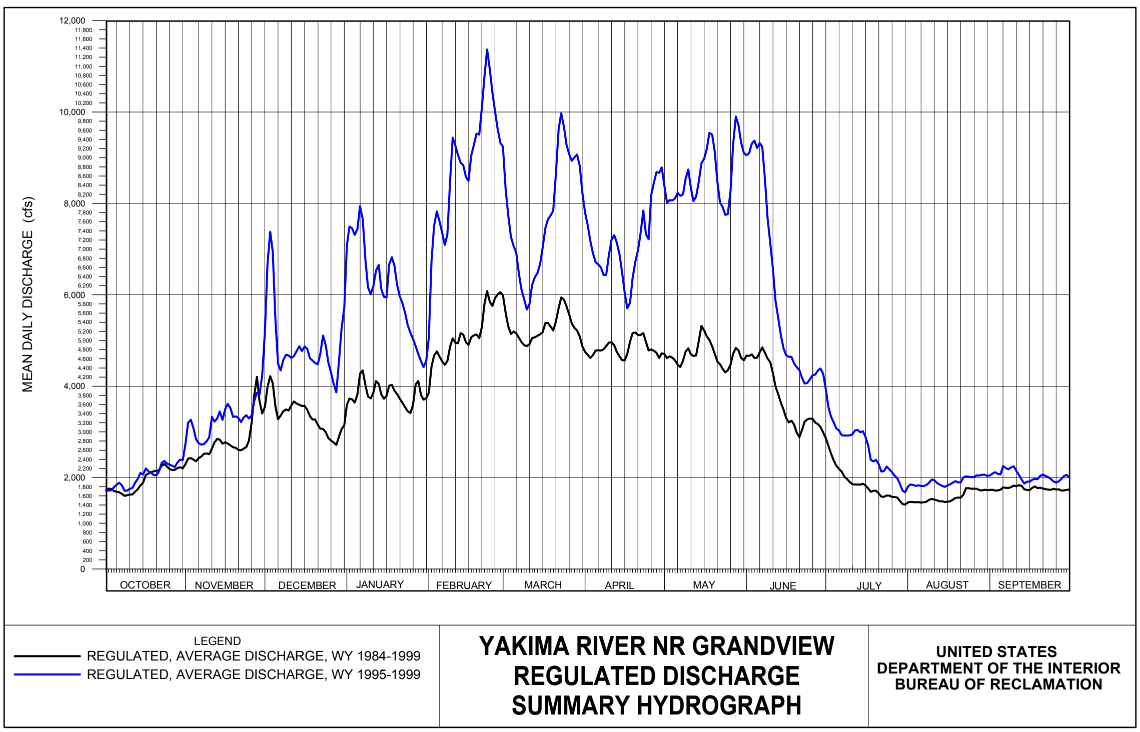
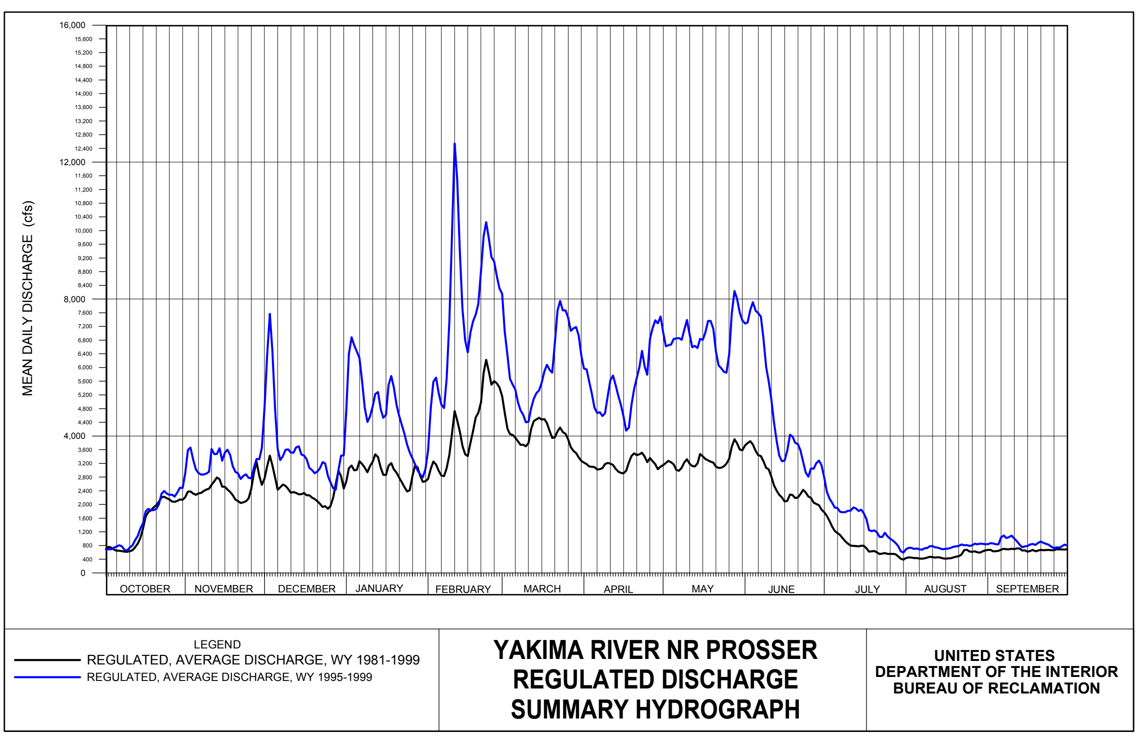
The Yakima River near Grandview (YGVW) regulated discharge hydrograph provides some representation of the natural inflow available below the PARW site. During the non-irrigation season, YGVW shows very good inflow production and variability from the Satus and Toppenish Creeks' drainage basins. During the irrigation season, a large percent of the natural runoff from these creeks is diverted for irrigation, but at the same time, the irrigation return flow drains will also begin increasing from the increased diversion of the irrigation districts. The average annual actual flow passing the YGVW site is 1,975,288 acre-feet. This is an increase of 320,370 acre-feet over PARW's 1,654,918 regulated flow, and is a representative total for natural and return flows for this reach.

Yakima River near Grandview



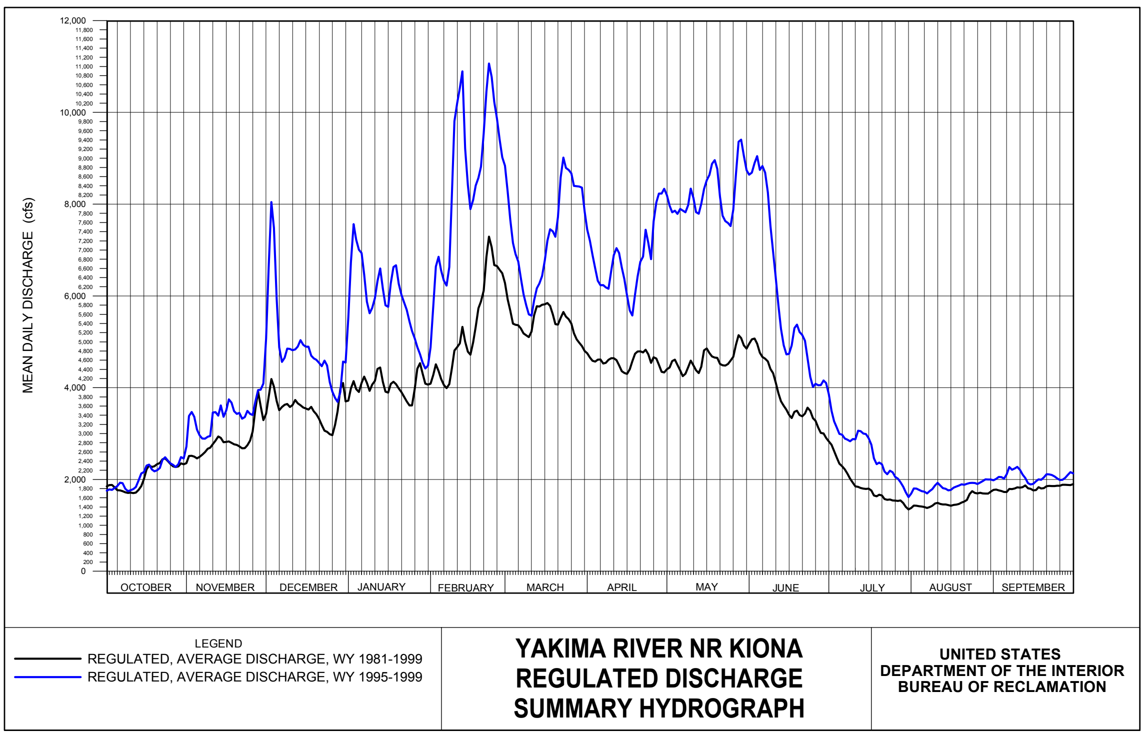
The Yakima River near Prosser (YRPW) regulated discharge hydrograph provides some representation of the natural flow available below the PARW site. During the non-irrigation season, YRPW shows very good inflow and variability from the Satus and Toppenish Creeks' drainage basins, and other creeks located between PARW and YRPW. During the irrigation season, a large percent of the natural runoff from these creeks is diverted for irrigation, but at the same time, the irrigation return flow drains will also begin increasing from the increased diversion of the irrigation districts. The average annual actual flow passing the YRPW site is 1,594,751 acre-feet. YRPW hydrograph regulated flows volume shown is reduced due to the year around annual diversion of 722,359 acre-feet, Chandler Power Canal (CHCW) for power production which includes 97,839 acre-feet annual diversion for Kennewick Irrigation District. These volumes total 2,318,110 acre-feet for this end of the reach between PARW and Prosser Diversion Dam, and is an increase of 663,192 acre-feet over PARW's 1,654,918 regulated flow, and a representative total for natural and return flows for this reach. Note: of the 722,359 acre-feet diverted by CHCW for power production and irrigation demands, 624,520 acre-feet is returned to the river system 10.5 miles below YRPW gaging site. PARW is the controlling site for calculation of TWSA, which is used to establish YRBWEP target flows for YRPW from April through October. These YRBWEP target flows (300, 400, 500, or 600 cfs based on TWSA) set the minimum instream regulated flow for this period of time. Instream flows are also established for power subordination and spawning/incubation flows.

Yakima River near Prosser

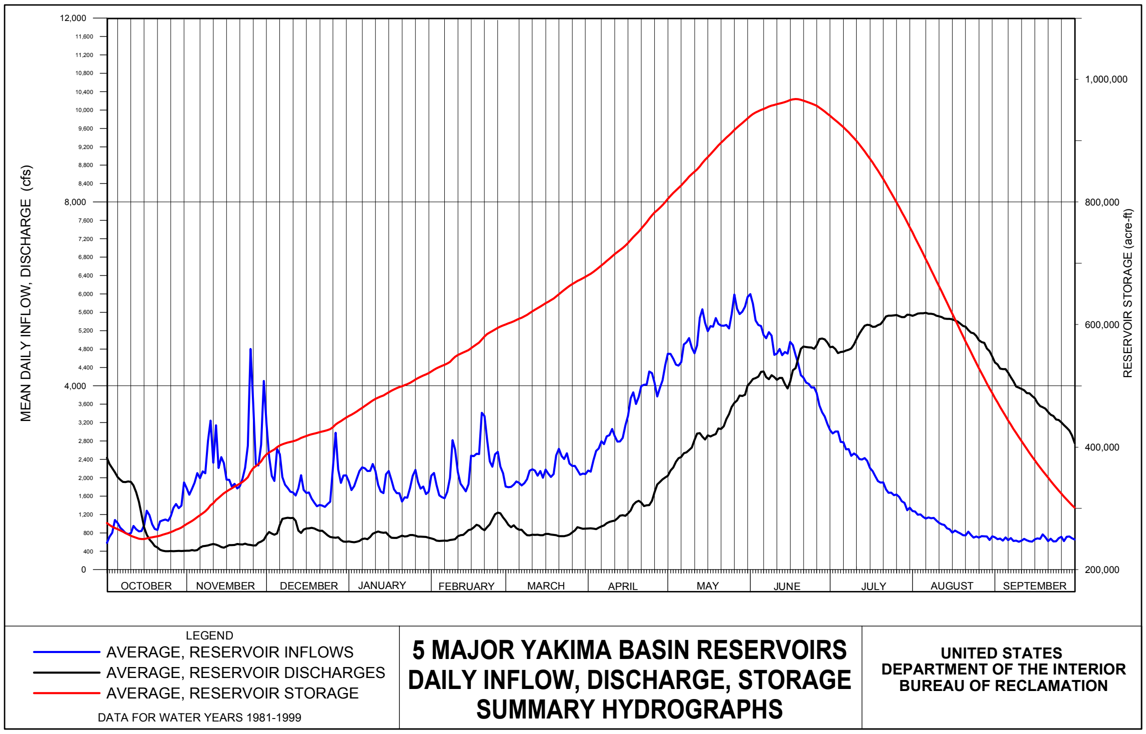


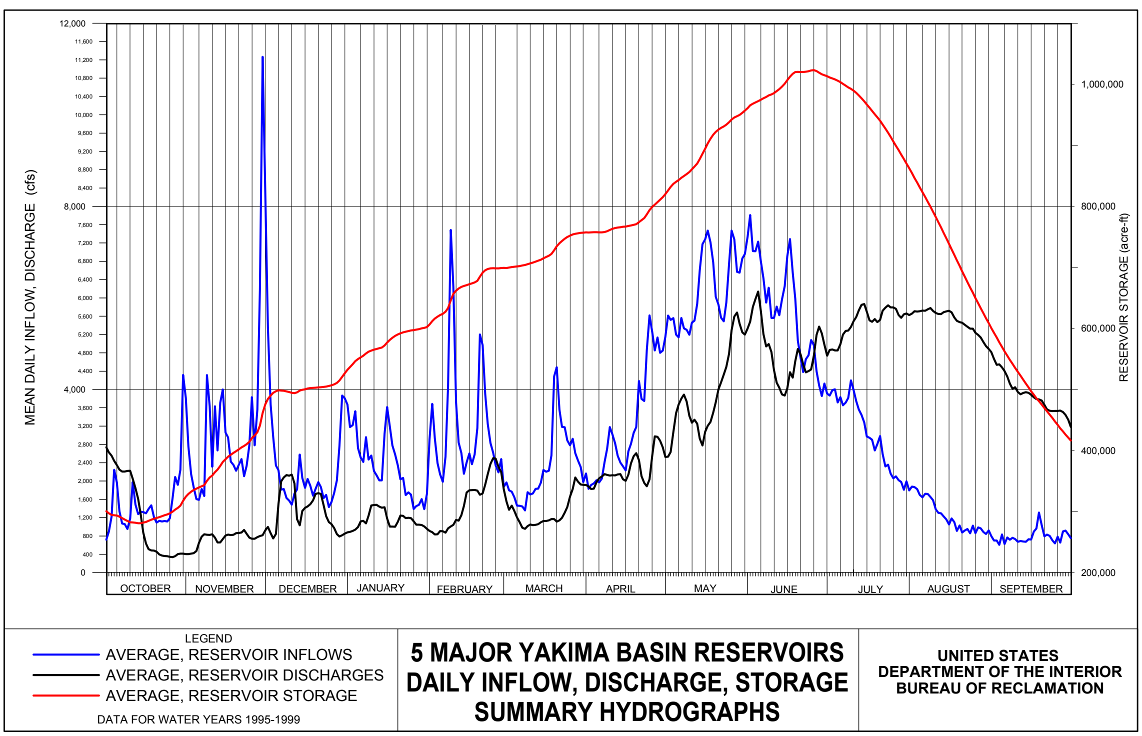
The Yakima River near Kiona (KIOW) regulated discharge hydrograph provides some representation of the natural flow variability available in the lower Yakima River basin. During the non-irrigation season, KIOW shows very good inflow and variability from the Satus and Toppenish Creeks' drainage basins, and other creeks located between PARW and KIOW. During the irrigation season, a large percent of the natural runoff from these creeks is diverted for irrigation, but at the same time the irrigation return flow drains will also begin increasing from the increased diversion of the irrigation districts. There is up to 400+ cfs of daily diversion during irrigation season below the KIOW site and the mouth of the Yakima River. The average annual natural flow passing the KIOW site is 3,970,000 acre-feet (period of record = 1961-1990) with average annual actual/regulated flow total of 2,351,186 acre-feet (59%). Of the KIOW basin average annual natural flow, 1,713,282 acre-feet (43%) is regulated by storage reservoirs, delaying and modifying discharge timing and volume rate of flows by as much as 114 days at the KIOW site.

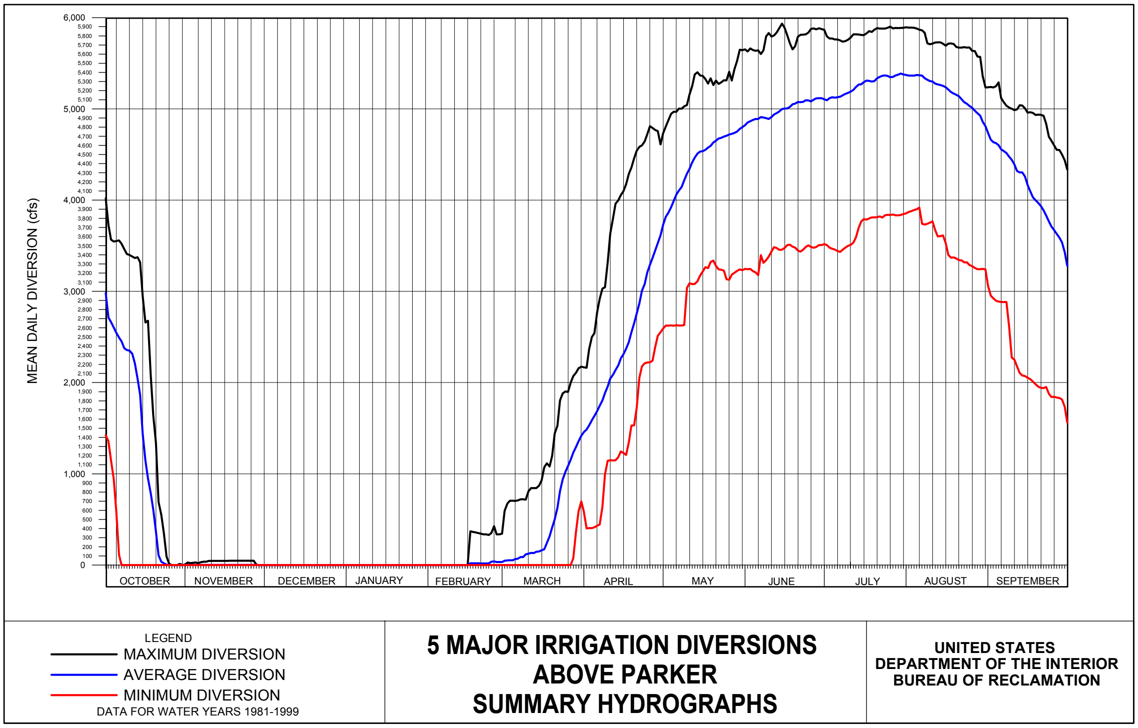
Yakima River near Kiona



System Information – Total of 5 Major Reservoirs and 5 Major Diversions







The first two of the preceding three summary hydrographs represent the combined totals of the five major Yakima basin reservoirs' (Keechelus, Kachess, Cle Elum, Bumping, and Rimrock) daily natural inflow, regulated discharge, and storage content. These graphs provide a combined storage overview of the effects of regulation by storage reservoirs, show the delaying and modifying natural flow timing and volume rate of flows by as much as 6 months. The third summary hydrograph represents the combined totals of the five major Yakima basin irrigation diversions above Parker: KRD, RID, YTID, WIP, and SVID, and shows the timing of peak irrigation demands during the normal low natural runoff season of July through mid-October.

6.2 FISHERY RESOURCES

Numerous factors have affected the fishery resources in the Yakima basin. These include out-of-basin factors such as the hydroelectric dams built on the Columbia River and commercial fishing, as well as those that have occurred within the basin associated with various land use practices (e.g., timber harvest and agriculture), floodplain development, road and railway construction, and irrigation development. Irrigation development includes the construction, operation, and maintenance of the Yakima Project and the lands it serves, the focus of this section. Many fish species are present, or were once present, in the Yakima basin (see section 2.8.2); however, the effects of the project on some species have not been well studied. Of those for which information is available, specific attention will be given to native species and include steelhead and bull trout (both currently listed as threatened under the Endangered Species Act

[ESA]), chinook salmon (fall- and spring-run), coho salmon (considered extirpated, but recently reintroduced), and sockeye and summer chinook salmon which were extirpated and continue to be absent from the basin.

Information for this section was primarily obtained from discussions with fisheries biologists working in the Yakima basin; the Biological Assessment for the Yakima Project; preliminary results of the Ecosystem Diagnostic and Treatment (EDT) model currently under development by the Yakama Nation; and the draft final report entitled "The Review and Synthesis of Ecological Studies in the Yakima River, Washington, With Emphasis on Flow and Salmon Habitat Interactions" (Snyder and Stanford, 2001). Important information is continually being collected, summarized, and reported. The material in this section attempted to incorporate the latest information available. As this is a working document, new information will be incorporated upon the receipt of the Biological Opinions for the Yakima Project by the National Marine Fisheries Services (NMFS) and the U.S. Fish & Wildlife Service (FWS), the completion of the EDT, Northwest Power Planning Counsel's Subbasin summary, and studies currently being conducted by Dr. Jack Stanford under contract to YRBWEP.

There are references in this report to models and other analytical methods for evaluating the impacts of various human activities on salmonid and other natural resources in the Yakima basin. These various tools are used by scientists and other professionals as guides to arrive at recommendations for changes in operations, studies, monitoring protocols, and other actions to improve habitat conditions for salmonids in the Yakima basin. The reference to these models and analytical methods is not meant as an unqualified endorsement of any of them specifically. Nor is the reference to these tools meant to be a recommendation for their future use by any agency or other entity. They have been included to reference the various sources from which information was gathered to arrive at the analyses in this report.

As was described in section 5, the Yakima Project is an extremely complex system which affects various reaches of the Yakima River and its major tributaries differently, even during the same time periods. For this reason, this section will assess the effects of Yakima Project operations on fishery resources reach-by-reach. Sub-reaches within each assessment reach are addressed where appropriate. The eight assessment reaches include:

1) Upper Yakima River from Keechelus Dam downstream to the Roza Diversion Dam (86.5 miles), including Keechelus and Kachess Reservoirs and their tributaries.

2) Cle Elum River from Cle Elum Dam downstream to the confluence with the Yakima River (8.2 miles) and Cle Elum Reservoir and its tributaries.

3) Middle Yakima River from the Roza Diversion Dam downstream to the Prosser Diversion Dam (80.8 miles), including any drains which were formerly natural waterways.

4) Lower Yakima River from the Prosser Diversion Dam downstream to the confluence with the Columbia River (47 miles), including any drains which were formerly natural waterways.

5) Bumping River from Bumping Dam to the confluence with the Little Naches River (16.6 miles) and Bumping Reservoir and its tributaries.

6) Upper Naches River from the Bumping River confluence downstream to the confluence of the Naches and Tieton Rivers (27 miles).

7) Tieton River from Tieton Dam, including Rimrock Reservoir and its tributaries downstream to the confluence with the Naches River (21.3 miles).

8) Lower Naches River from the Naches/Tieton confluence downstream to the confluence of the Naches and Yakima Rivers (17.5 miles).

The construction, operation, and maintenance of the Yakima Project has had a profound effect on the Yakima River ecosystem and the fish populations dependent on it. Four components of the project are considered to be the primary contributors to the decline of native fish resources. These include: 1) storage dams constructed in the upper portion of the basin; 2) diversion dams constructed throughout the basin; 3) effects of flow regulation on fish habitat availability, in-basin survival and productivity; and, 4) effects of the project on water quality. A brief overview of these components follows. Each component is discussed in detail, where applicable, within each assessment reach.

Storage Dams -

Six storage dams have been constructed in the Yakima Basin. Four of these were located at the outlets of natural lakes, including Bumping (1910), Kachess (1912), Keechelus (1917), and Cle Elum (1933). Clear Lake Dam (1914) and Tieton Dam (1925) created new reservoirs by inundating the upper Tieton River basin. Numerous fishery related impacts are associated with their construction.

The reservoirs created by the dams flooded a considerable amount of pristine, high quality fish habitat. Where natural lakes were present they were much smaller than the current reservoirs and miles of stream were lost. The habitat in these historic lake basins was utilized by sockeye, a species which spawns in flowing water, but whose young rear in lakes; and by bull trout, which are present in all of the reservoirs and spawn in tributary streams. It can be reasonably assumed that other anadromous salmonids, particularly steelhead, which are known headwater spawners, utilized this habitat as well. In the case of Tieton Dam, an extensive meadow complex was inundated. The area was almost certainly valuable habitat for bull trout and all native anadromous salmonids, with the probable exception of sockeye.

Even if this habitat were still viable, neither it nor any existing habitat upstream has been accessible to anadromous salmonids since construction of the storage dams. None of these dams is equipped with fish passage facilities. This condition has been most devastating to sockeye salmon which were extirpated in the Yakima basin following the completion of the last storage dam on the Cle Elum River in 1933, if not earlier. The absence of passage has also isolated local populations of bull trout, prohibiting the exchange of genetic material between populations, and preventing the recolonization of populations diminished by catastrophic natural events. Although bull trout populations isolated in Rimrock are considered healthy, fishery biologists addressing recovery of bull trout believe lack of passage to be a major contributing factor in the decline of this once abundant species. It should also be noted that the outlet works for all of the storage dams in the Yakima basin are unscreened. Passage through these outlets can kill and injure fish. The potential for this to be a problem is increased as reservoirs are drawn down late in the irrigation season.

The Yakima Project storage dams also impede or preclude movement of sediment and organic material (e.g., woody debris) to the river downstream. Additionally, gravel movement in the Tieton River is impeded due to the Tieton Dam. The consequential effects on channel morphology, substrate characteristics, habitat quality, and productivity are usually significant. The downstream migration of bed materials is an essential process which maintains channel complexity and thus habitat quality. The recruitment of gravels and small cobbles, essential for the construction of redds by spawning salmonids, is necessary to replace those that are inevitably washed downstream. Coarse particulate organic matter, ranging from large trees to leaf litter, is an important energy and structural component of all riverine ecosystems. Large woody debris (LWD) provides physical habitat for both fish and aquatic invertebrates, while leaf litter is an essential energy source in the food chain that drives stream productivity.

Diversion Dams -

Six major diversion dams are a part of the Yakima Project (Easton, Roza, Sunnyside, Wapato, Prosser, and Yakima-Tieton) and other non-Reclamation operated facilities (Wapatox and Wanawish) have a significant influence in the operation of the Yakima Project. Other diversion dams of note are listed in table 6-7. Reclamation operated diversion dams are maintained within NMFS criteria. However, all diversion dams effect fishery resources regardless of how well they are operated or maintained. These effects include passage/entrainment problems at ladders, screens and bypasses (this includes delays); predation below dams or at bypass returns; adverse maintenance schedules and operating protocols; disruption of bed load transport and deposition; and impediments to transport of LWD. These concerns are addressed specifically at each project diversion.

Table 6-7. – List of non-Reclamation operated diversion dams in the Yakima River basin that are considered in operation decisions.

Diversion Dam	River Mile
Yakima River	
West Side	166.1
Ellensburg Town Canal	161.3
Selah-Moxee	123.6
Moxee	115.9
Naches River	
Naches-Selah	18.9
Naches-Cowiche	3.6

Diversion dams inherently cause passage problems. However, if they are properly designed, maintained, and operated within NMFS criteria they provide passage for anadromous salmonids and most other species. The above diversion dams are now equipped with facilities that generally operate within currently accepted NMFS criteria and pass the anadromous species of fish. However, fish protection facilities were not designed to protect most native resident species and these species do experience passage problems (adult lamprey cannot ascend ladders and very small resident fish, stickleback and dace can be entrained behind screens). Additionally, several fish screens and a few bypass outfalls, particularly in the lower river, have created conditions conducive to significant avian and piscivorous fish predation mortality.

It is generally believed that minor passage delays at a diversion dam do not pose a significant problem to emigrating smolts. The cumulative effects of delays at several diversion and hydropower dams may impact smolt migration, but it is unknown at this time what those impacts are.

While Reclamation attempts to accommodate fish when performing operation and maintenance activities, non-fish related operations and maintenance issues associated with Reclamation's contractual commitments are generally treated with higher priority (i.e., installing flashboard to ensure that diverters get their full allotment of water). Additionally, some maintenance activities can essentially pit various life stages of the same species against each other. An example would be fall screen maintenance which helps protect juvenile fish, but also alters flow levels below the Roza and Prosser Diversion Dams at a time when adult fall chinook and coho are spawning. During routine maintenance, debris is sometimes removed from diversion structures, and likewise, from the river. This debris would provide important organic material for productivity. Another effect of operations and maintenance activities for irrigation and flood control is the resultant flow fluctuations and occasional release of fine sediments, both of which affect fish life and habitat.

Annual maintenance of the fish screens takes a minimum of 4 weeks per site. In many cases, it is necessary to dewater the screens before maintenance work can be completed. It takes about 3 days to dewater the large main canals in order to work on the screens. The dewatering process places fish at risk in areas where the water pools in depressions rather than draining directly to the river via the fish bypass system. Sites where water can pool during the dewatering process include the Chandler, Sunnyside, Wapato, Roza, and Easton screen sites. Sites where fish can be stranded include Chandler, Sunnyside, and Roza. As dewatering occurs, if fish are noted ahead of the screens, State biologists are requested to help with fish salvage, if possible. Maintenance and repair of hydropower facilities are generally coordinated with annual screen maintenance, however, this is not always the case and is discussed in those affected reaches.

Diversion dams affect the transportation of bed material (fine and course sediment) and LWD, which affects fishery resources. The geomorphic consequences and their effects on the fishery resources are difficult to describe. Habitat complexity is reduced downstream because key physical components are being removed or restricted.

Flow Regulation -

Project operations significantly alter the timing and magnitude of flow in most reaches of the basin. These effects vary across space and time. For example, while some reaches are subjected to much higher than natural flows from July to September, other reaches experience much lower than natural flows during this time period. Further, the manner and magnitude of project effects to the basin hydrograph varies significantly by water year. During the relatively wet year of 1997, project operations severely dampened the magnitude and extended the duration of the spring peak flow. During the dry year of 1994, project operations essentially eliminated the spring peak flow. While the ecological consequences of those deviations from the unregulated conditions have not been fully described, they are undoubtedly more pronounced during dry water years.

Fluctuation of flows related to the operation of the project has been identified as a possible concern for rearing juveniles and the food web. Significant fluctuations in the flows on a weekly, daily, or even hourly basis may cause cyclic dewatering and re-watering of the near shore habitat, which could result in reductions in biotic productivity (Perry et al., 1986; Reckendorfer et al., 1996; Schiemer et al., 1991; Travnickey et al., 1995; Weisberg et al., 1990). The effects of flow fluctuations can vary depending upon many factors, such as the physical characteristics of the river and the severity of the fluctuation. The stranding of salmonid fry during flow fluctuations has been documented in northwest streams (Stober et al., 1981; Woodin, 1984). Flow fluctuations alter macro-invertebrate production (Ward, 1976; Becker et al., 1981; Cushman, 1985; Jordonnais and Hauer, 1993) and thus could potentially reduce the food base. These fluctuations can have immediate lethal effects to fish, or indirect or delayed biological effects to fish and river productivity (Hunter, 1992).

Water flow is related to several environmental attributes such as: water quality (temperature), sediment dynamics, riparian vegetation, floodplain connectivity, and many other ecological processes. Regulation of the flow compromises these processes and inherently affects fish and other aquatic organisms. Flows mimicking a natural hydrograph result in the greatest benefit to the aquatic environment and the fisheries resources associated with them (see Snyder and Stanford, 2001; and System Operations Advisory Committee [SOAC], 1998 for summary). To affect this recovery, a normative ecosystem approach should be adopted. A normative ecosystem provides for “properly functioning conditions” (PFC), standards that are essential to maintain diverse and productive populations while accommodating uses to the extent practicable. The “normative river ecosystem” combines physical habitat with a flow regime designed to create and maintain a continuum of high quality habitat for all biota, primary production (algae), secondary production (benthic invertebrates), and the various life history stages of the native fish assemblage. Before development, the natural hydrograph interacting with the channel, floodplain, and shallow groundwater system formed the physical template within which native species evolved. The challenge of the normative ecosystem concept is to identify and recreate those key features of the natural hydrograph and physical habitat necessary to restore “properly functioning ecosystems” while continuing to meet human needs.

Hydrographs comparing unregulated runoff to regulated runoff in relation to magnitude, frequency, duration, timing, and rate of change at several locations in the basin are displayed in section 6.1.2. A larger difference in flow regime between regulated and unregulated indicates a greater negative effect on the aquatic ecosystem. Comparing regulated to unregulated hydrographs is only a starting point for describing the effects of flow manipulation. Using tools like the “Range of Variability Approach” (RVA; Richter, B.D. et al., 1997) and an ecological model such as EDT may provide greater resolution in determining relative effects on key species of concern such as salmon and steelhead. Monitoring should be conducted to assess the validity of any ecological model used.

Water Quality -

The Yakima Project affects water quality as described in section 6.1.1 of this document. Water quality has improved recently through better management of return flow from agricultural drains. The specific effects of compromised water quality on fish are sometimes difficult to describe. Some effects are direct, such as fish consumption advisories for resident fish that bio-accumulate pesticides in the lower river. Other effects are indirect such as modifying the aquatic insect community due to pesticide contamination or sedimentation, which in turn adversely affects the fish community. Project operations that affect water quality detrimental to fish are described for each reach.

6.2.1 Upper Yakima River

The upper Yakima River is broken down into several sub-reaches which are described below.

Storage Dams

Keechelus Dam and Reservoir -

The effects on the native fishery and the physical processes necessary to maintain habitat, resulting from the construction of Keechelus Dam, were generally described previously in this section. While native species distribution before construction of the dam is unknown, coho, and sockeye salmon as well as steelhead trout were all historically reported to have been present above the structure. A significant amount of spawning and rearing habitat exists in the numerous tributaries which flow into Keechelus Lake. The dam permanently blocked access to this habitat. In addition to this habitat, the reservoir inundated an additional 4-5 linear miles of habitat in the low gradient sections of these streams flowing into the lake.

An isolated population of bull trout resides in Keechelus Lake and spawns in Gold Creek. Adult spawners migrate from the lake in July and August when Gold Creek flows are usually low and the reservoir is drawn down. These fish may encounter impassable conditions in the portion of the stream flowing across the exposed lake bottom where the channel is not well-defined. During the summer of 2000, passage conditions through the inundation zone were marginal at best (Jeff Thomas, FWS, Yakima WA, personal communication, 2000). Additionally, a portion of the creek near Gold Pond generally dewaters in late summer particularly in low water years.

Kachess Dam and Reservoir -

Kachess Dam also presents general problems associated with storage dams. Approximately 1 mile of tributary habitat is seasonally inundated. While native species distribution before construction of the dam is unknown, coho and sockeye salmon as well as steelhead trout were all historically reported to have been present above the structure. Adult migration into and out of Box Canyon Creek, the primary spawning tributary, may be affected by the annual drawdown of the lake. As the lake is drawn down, the exposed stream channel on the lake bottom becomes ill-defined as it flows across the permeable lake sediments and may be too shallow for bull trout passage. In the fall of 1996, Reclamation constructed a single channel through the inundation zone. The project was successful in providing bull trout passage in 1997 and 1998 (above normal water years), but downstream passage problems may still persist particularly for adults returning to the reservoir. In a dry water year when the reservoir is drafted to a lower level, upstream passage may still be a problem.

Passage problems for bull trout also occur in the Kachess River as it annually dewaters above the inundation zone. It is not clear what processes are contributing to stream dewatering. Adfluvial adults were observed in the river above the reservoir for the first time in October 2000. These fish were observed after the river established a surface water connection with the reservoir shortly after a rain event. In late October 2000, two dead adult adfluvial bull trout were found in an isolated pool in the inundation zone (Eric Anderson, Washington Department of Fish and

Wildlife [WDFW], Yakima WA, personal communication, 2000). Kachess River had lost connection with the reservoir after adfluvial fish had entered the stream.

Diversion Dams

Lake Easton Diversion Dam -

The fish ladder at Easton was rebuilt in 1987, to meet NMFS passage criteria for anadromous salmonids. A counting and imaging device was installed in October 2000, which should help determine if bull trout are able to use the ladder. The fish ladder is operated all year except during water-short years when it may be closed from May through October. This is done to prevent spring chinook salmon from spawning in an area which cannot be protected from dewatering because of a competing need to fill Kachess Reservoir (see mini flip-flop in section 5.2.5). Reclamation generally closes the ladder after consultation with SOAC and others. Closure occurs approximately 1 out of every 10 years.

During the irrigation season, but prior to spring chinook spawning, sediment is flushed from behind Easton Dam through the sluice gates. This sediment can impact the ecosystem downstream of Easton Dam. In the past, and under certain circumstances, when the sluice gates were opened sediment flushed to the area downstream, which is spring chinook spawning habitat. This maintenance procedure has now been altered. The sluice gates are opened periodically throughout the year to remove sediment incrementally. For example, the sluice gates are opened in the spring when flows are high, so that the sediment can be dispersed. Now, when the gates are opened during the fall maintenance activity, the sediment load is relatively low and thus impacts to spring chinook redds are minimized.

There are no identified fish issues related to the screens or maintenance of them at Easton Diversion Dam.

Flow Regulation

Keechelus Sub-Reach -

The Keechelus sub-reach extends from Keechelus Dam downstream to Lake Easton (11.5 miles). Flows in this reach are largely controlled by releases from Keechelus Reservoir (hydromet gage KEE). This reach contains high quality habitat, the suitability of which is compromised by the flow regulation. Regulated summer flows, on average, exceed the estimated unregulated spring peak flow. Regulated flows based on daily average during irrigation season in June, July, and August range from 2 to 10 times greater than the estimated unregulated (natural) flows and last almost twice as long in duration (see figures on page 6-21). Flows of this magnitude and duration can displace rearing salmonids, impede the establishment and development of riparian habitat (a key provider of cover and food for all fish), and negatively affect the invertebrate community. Food may be a limiting factor for rearing salmonids in the upper Yakima River (Todd Pearson, WDFW, Ellensburg WA, personal communication, 2001). In early September, the flow is reduced over a 10-day period, from approximately 1,200 cfs to 100 cfs, with the onset of the flip-flop and mini flip-flop operation (see section 5.2.5). This can strand or displace juvenile fish, disrupt spawning bull trout, strand invertebrates, and reduce the benefits of the riparian cover as the channel moves away from its banks.

In November, following the spawning period of both spring chinook salmon and bull trout, flows are further reduced at the onset of the winter storage period. While this appears to provide protection to these redds with respect to surface flows, there are indications that subsurface (i.e., hyporheic) flow conditions are affected by reductions in surface flows (Mark Bowen, Reclamation, Denver CO, personal communication, 2001). The streamflow is set by the Field Office Manager, after consultation with SOAC, irrigation district managers, and his environmental staff and others, in an attempt to provide flowing water at a depth of no less than 2 inches over the tailspills of established redds. A study is currently underway in the Yakima basin to determine if there are any effects on salmonid egg survival resulting from flow reductions following the spawning period. It should be noted that this is not a natural hydrologic condition.

Flows usually begin to increase in December, but can be highly variable year-to-year depending on weather, carryover storage, and the need to evacuate some Keechelus storage to meet flood control guidelines. From October through March the regulated flow remains fairly steady, unlike the dynamic natural flow, and is maintained at a much lower magnitude. This reduces the amount and quality of winter rearing habitat for juvenile fish protected the previous winter during the egg/alevin life stage. Spring peak flows are also reduced.

Kachess Sub-Reach -

The Kachess sub-reach is comprised of the Kachess River from Kachess Dam to its confluence with Easton Lake (1 mile). Regulated flows from Kachess Reservoir are presented from hydromet data gathered at KAC (see figures on page 6-23). This reach is of limited value as fish habitat because of its severely altered hydrograph and short length. Regulated flows during the October through May reservoir refill period are severely reduced and lack natural fluctuation. This severely reduces the available habitat for rearing juveniles. Peak flows do not occur during the usual May through June period and are a contributing factor to poor emigration cues experienced in downstream reaches. The sustained high flows that are released from Kachess Dam in September and early October during the mini flip-flop operation, are drastically reduced in mid-October after bull trout and spring chinook salmon spawn, which could leave redds dewatered. In past years, Kachess River downstream of the dam was dewatered in the fall and winter during reservoir refill operations. With the implementation of the mini flip-flop operation, this reach has essentially been sacrificed to protect spring chinook salmon redds in other upper Yakima River reaches (Keechelus, Easton, and Cle Elum) with great amounts of high quality spawning and rearing habitat.

Yakima River at Easton Sub-Reach -

The Easton sub-reach extends from Easton Diversion Dam downstream to the confluence of the Cle Elum River (16.5 miles), and provides highly suitable spawning and rearing habitat for spring chinook salmon. This sub-reach is the most productive spring chinook spawning area in the Yakima basin. The hydrograph that depicts this reach is EASW (see figures on pages 6-25 thru 27). The regulated flows in the Easton reach match the fluctuating pattern of a natural hydrograph from November through February, although at a reduced magnitude. Starting in March, larger differences between regulated and unregulated flows begin to appear and by May peak flows are reduced by nearly two thirds. This reduction in flow is the result of reservoir storage and diversion to the KRD at Easton Diversion Dam. This affects emigration cues for anadromous smolts rearing in the upper river and downstream reaches as well. Beginning in late July, regulated flows more closely mimic that of unregulated flows in magnitude, but still slightly higher. In early September, flows are dropped for flip-flop so that spring chinook spawn at a lower flow, thus making it possible to provide incubation flows during the winter storage period. Initial spawning flows are “near-unregulated” flow levels, but as rains begin to fall in October, spawning flows remain steady whereas the unregulated flows increase and can show much variation.

Yakima River at Cle Elum Sub-Reach -

This sub-reach extends from the confluence of the Cle Elum River to Roza Dam (57.5 miles). The Ellensburg Town Diversion Dam, a channel spanning diversion dam, is located in this reach and flows are described by the hydromet gaging station UMTW (Yakima River near Umtanum; figures on pages 6-36 & 37). This upper portion of this reach is an important spawning area for spring chinook and the entire reach provides rearing habitat. It also provides a popular rainbow trout fishery. Anadromous salmonid movements are effected by seasonal flow patterns and reduced peak flow (nearly 50% unregulated) in early spring. Conversely, abnormally high flows occur from the beginning of July through early September when flip-flop is initiated. By mid-August streamflows in this reach average 600 percent of those which would occur under unregulated conditions and undoubtedly affect the feeding behavior of juvenile salmonids. Preliminary results from studies examining the stomach contents of these fish have shown that they are not feeding efficiently (Todd Pearson, WDFW, Ellensburg WA, personal communication, 2001) and suggest that this may be a factor limiting production. Another likely effect of these midsummer peak flows is the downstream displacement of juvenile salmonids. Finally, flows which diverge from the natural flow regime to this extent could be expected to alter the composition and diversity of the aquatic invertebrate community, the primary food source of juvenile salmonids. With the implementation of flip-flop in early September, streamflows are drastically reduced to a level representing a natural flow condition which persists for approximately 1 month. The sudden change in river stage strand invertebrates and thus affects the food base.

A daily pattern of river flow fluctuations are recorded at the Umtanum gaging station in the Yakima canyon reach RM 147-127 (see figure 6-1). This fluctuation appears to be related to the return flows from the Kittitas Valley above the canyon. Gaging stations above the Kittitas Valley do not show the same kind of regular, large fluctuations.

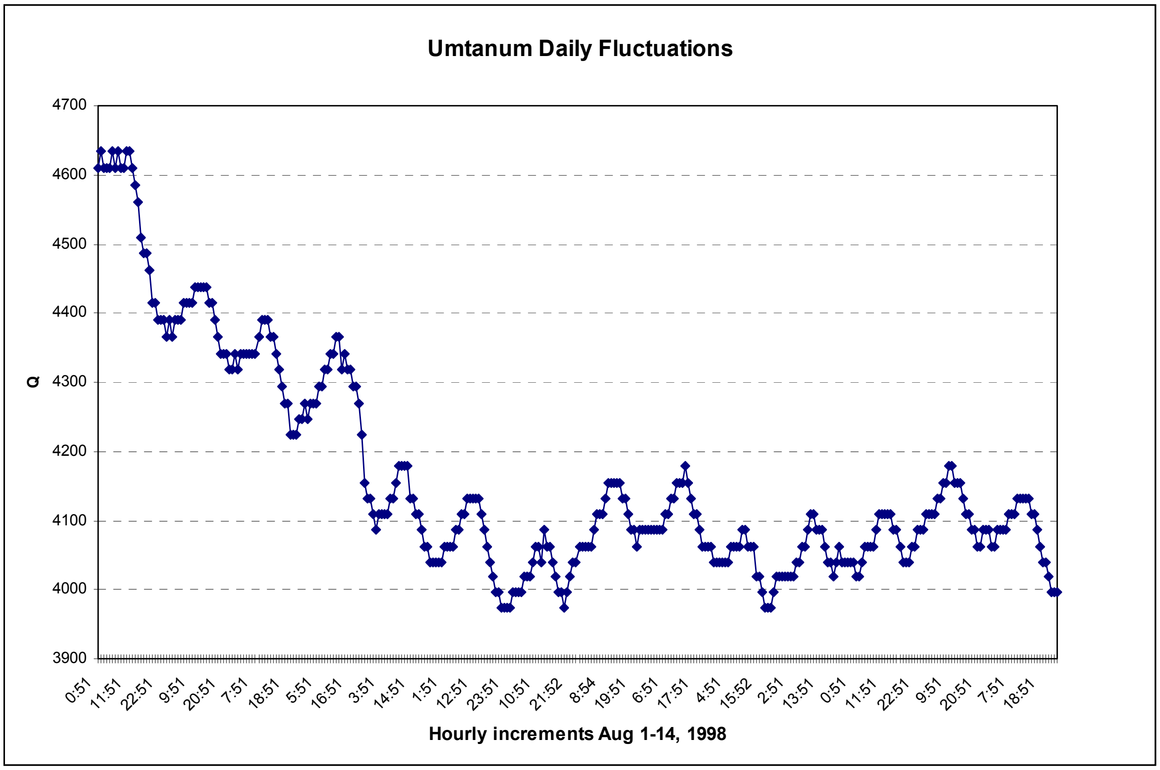


Figure 6-1

Water Quality

Water quality in the Upper Yakima River is considered good above the confluence with Wilson Creek.. Wilson Creek is used as a large agriculture return within this reach and enters the Yakima River at the head end of the Yakima Canyon (RM 147). The quality of water in Wilson Creek is degraded by FC, heavy sediment loading during the irrigation season, and pesticides.

John Vaccaro's temperature model simulations indicated that flow regulation would actually produce lower July - August temperatures in the upper Yakima River than the unregulated condition (Vaccaro, 1986). Other water quality parameters may also be affected.

6.2.2 Cle Elum River

Storage Dams

Cle Elum Dam and Reservoir -

The project effects to fish which are common to all storage dams apply to Cle Elum Dam and Reservoir. Unique effects of project operations are unknown. Very little information is available on Cle Elum bull trout populations, and it is not known definitely whether lake drawdown is impeding bull trout passage into or out of Cle Elum Reservoir. In the fall after flows have been reduced for spawning spring chinook salmon, dead burbot (*Lota lota*), a species of concern in Washington State and a lentic species, have been observed just downstream of the dam. This documents that entrainment is occurring and could be worse during high flow releases.

Diversion Dams

Project diversion dams are not in this reach.

Flow Regulation

The Cle Elum River reach is 8.2 miles long and the flow is measured at the gage below Cle Elum Reservoir (CLE). The Cle Elum River, although limited in length, is also an important spring chinook spawning and nursery area in the upper Yakima River. The river is characterized by a broad channel with several large side channel complexes that do not become connected to the main river unless the flows are above 500 cfs. Approximately a quarter mile of river from the dam downstream to the Green Bridge is channelized. The Cle Elum River is dependent on releases from the reservoir for its inflow; there is no significant inflow from tributaries downstream from the reservoir. Regulated flows in the Cle Elum River represent a major alteration to the magnitude and timing of unregulated flow (see figures on page 6-29). Spring peak flows can be less than half of unregulated, severely impacting emigration cues to fish in downstream reaches. Summer (July, August, and early September) flows are extremely elevated due to peak irrigation deliveries prior to implementation of flip-flop, up to 10 times unregulated flows and protracted. Regulated summer flows are much higher than those which would occur during the spring under unregulated conditions causing downstream displacement of juvenile fish and severely compromising their ability to feed effectively. With flip-flop in early September, flows are drastically reduced from approximately 3,000 cfs to 300 cfs or less depending on available storage in the reservoir. This reduction can strand juvenile fish which have sought refuge in side channel habitat and strands invertebrates in areas now dewatered and thus affects the food base. There is usually a slight reduction in streamflow in November following spring chinook spawning to maximize storage while still attempting to protect incubating eggs. While redds may have been dewatered following this reduction in the past, Reclamation has been attentive to the situation in recent years and redd dewatering has not been a significant problem. The incubation flow level is held fairly constant over the winter until late March when releases from the dam gradually begin to increase. Flows during this period are approximately one third of what would occur under unregulated conditions. As mentioned above, there are several large side channel complexes on the Cle Elum River which are cut off from the main channel at flows below 500 cfs. These side channels would supply highly suitable winter rearing habitat for juvenile salmonids were they accessible.

Water Quality

Water temperature is affected when the project transitions to flip-flop operations (figure 6-2). A slight decrease in water temperature is evident and is related to a drop in flow. On September 8, 1998, flows were reduced from 1,200 cfs to 950 cfs; on September 9, 1998, flows were reduced from 900 cfs to 500 cfs; and finally on September 10, 1998, flows were reduced from 500 cfs to 200 cfs where they remained the rest of the winter. Water temperature is also likely affected at other times of the year in relation to alterations to the hydrograph, but data is not available to document this. The cause for the temperature change may be related to the way in which water was drawn from the reservoir, but this is only speculative at this time.

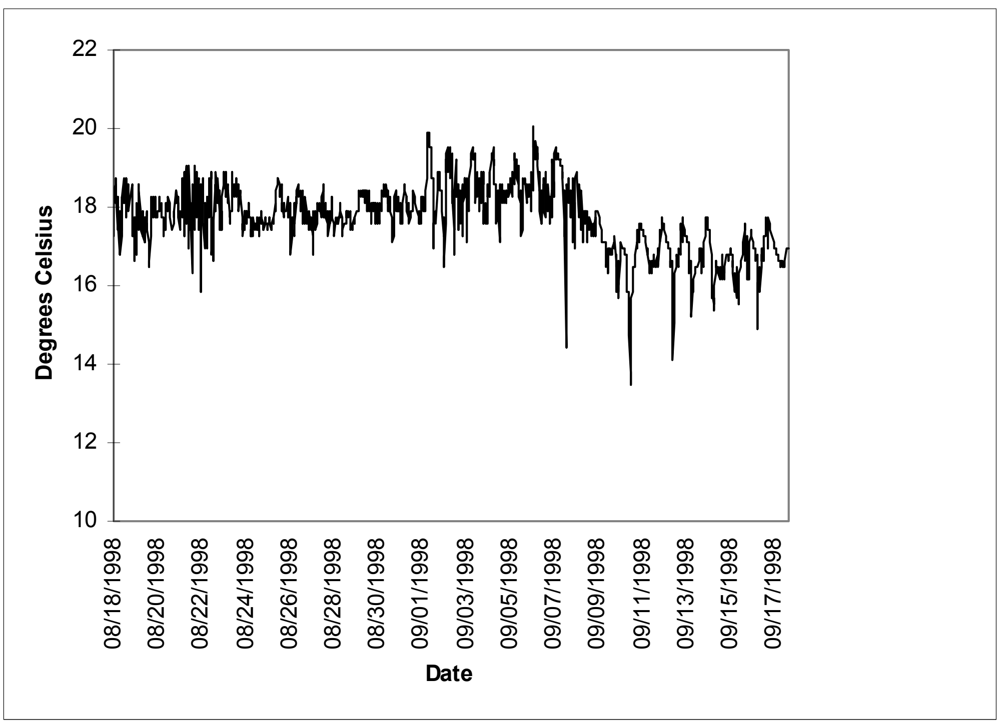


Figure 6-2. Water temperature (degrees Celsius) from August 18 through September 19, 1998, on the Cle Elum River. (Unpublished data, Pat Monk, consultant/fisheries biologist for Yakima Basin Joint Board.)

6.2.3 Middle Yakima River

The middle Yakima River is broken down into several sub-reaches which are described below.

Storage Dams are not present in this reach.

6.2.3.1 Roza Diversion Dam to Naches River Confluence

Diversion Dams

Roza Diversion Dam -

The fish ladder at Roza Diversion Dam meets current fish passage criteria for year-round operation. One atypical protocol has been employed to assist passage in the right bank fish ladder. As fish move into the entrance of the passage facility they tend to hang up or hold in a pool near the diffuser where extra attraction water is added. Occasionally the attraction water is turned off and the fish complete their assent of the ladder. Bull trout are occasionally seen passing the dam (personal communication, Mark Johnston, Fisheries Biologist, Yakama Nation, 2001). In 1990, the Yakama Nation installed a video camera in the ladder to count fish swimming past the diversion dam. The ladder is also equipped with a fish trap which is utilized to collect spring chinook salmon for the Yakima Klickitat Fisheries Project supplementation program. The fish screens and bypass also meet fish passage criteria. Large rainbow trout *(O. mykiss)* and juvenile spring chinook have been captured via electrofishing in standing pools behind the screens after the canal is dewatered for maintenance (personal communication, Mark Johnston, Fisheries Biologist, Yakama Nation, 2001). Additionally, a fyke net fished behind the screens in the spring of 1999 produced approximately one dozen rainbow trout and spring chinook salmon fry. Very little effort was afforded to this endeavor, approximately 2 weeks of effective sampling in April, due to equipment problems and poor sampling location (personal communication, Walt Larrick, Reclamation, 2001; and Mark Johnston, Fisheries Biologist, Yakama Nation, 2001). Further investigation was recommended to determine the magnitude of this occurrence.

The Roza Diversion Dam disrupts the natural sediment transport processes in this reach of the Yakima River. Prior to 1998, the gates at Roza Diversion Dam were raised prior to screen maintenance every fall season to dewater the screen site. This dramatically reduced the water in the Roza Dam forebay and released the accumulated sediment behind the dam. The released sediment resulted in the siltation of spring chinook and coho salmon redds below the dam. In 1998, a new dewatering process was utilized to prevent these adverse impacts where the dam gates are raised only enough to lower the pool to an elevation approximately 1.5 feet below the floor of the canal and fish screens. This reduced the amount of sediment flushed downstream. However, in December 2000, this established protocol was altered and resulted in a large amount of sediment being released. The specific effects to fish are unknown at this time, but the operation likely deposited sediment on spring chinook and coho redds.

Another maintenance concern associated with Roza Diversion Dam is stranding. Juvenile salmonids have been stranded in the afterbay and in the trough in front of the screens (20 to 30 juvenile salmonids were salvaged in 1998) when the canal is dewatered. The canal is not only dewatered for annual maintenance, but also to protect the screens when the river begins to freeze. The floor slab of the original screening facility has been notched and water and fish in the afterbay drain back to the river or escape through the original drum screen fish bypass slots and drains. Some fish are still stranded in the remaining pools and will die if not removed. Removal is difficult if ice builds up around the screens and covers the standing pools.

The operation of the roller gates is also a concern (see section 5.4). Operating just one gate may cause silt build up behind the passive gate and impede sediment transport. Periodic cycling of the two gates reduces or eliminates this effect.

Flow Regulation

Flows in the Yakima River from Roza Dam to the confluence of the Naches River (11.6 miles) are represented by the gaging station below Roza Dam (RBDW; see figure on page 6-38). Coho regularly spawn in this reach and occasionally steelhead, fall and spring chinook are observed. Likewise all these species also rear here. Unregulated discharge is not calculated at this site. Flows are characterized, in general, by high flows in the summer during irrigation season and low flows in the winter during reservoir storage and diversions for power production at the Roza Power Plant. The Roza Diversion Canal has the capacity to divert 2,200 cfs, approximately 1,260 cfs for irrigation and 940 cfs for power production. The non-irrigation season diversion could be up to 1,123 cfs for power production only. Water used to generate power is returned to the Yakima River 14.6 miles downstream of the diversion dam. Reclamation maintains an informal agreement (circa late 1980s), in consultation with SOAC and others, to maintain a 300 cfs minimum flow (400 cfs when power is being generated) below Roza Dam. The reach directly below Roza is confined to a large extent by canyon walls. Further downstream it is characterized by a single channel confined by dikes and bank protection.

Flow fluctuations are a concern below Roza Diversion Dam as the daily fluctuations seen at the Umtanum gage can be accentuated or dampened by the operation of the large roller gates at the Roza Diversion Dam (figure 6-3). This fluctuation in the river flow is moderated by the inflow of the Naches River at the end of the sub-reach.

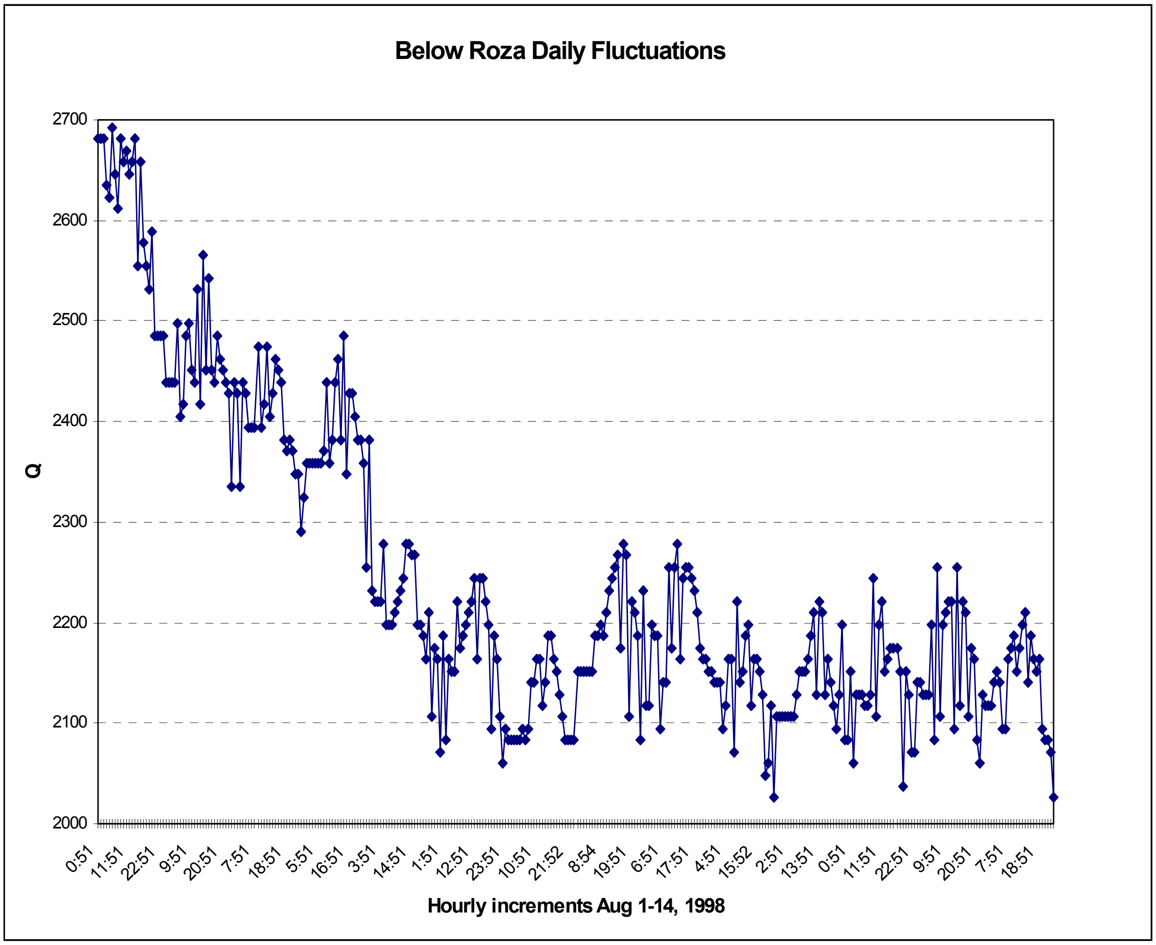


Figure 6-3. Hourly flows at the Below Roza Gage for the period of August 1-14, 1998.

In the late fall or early winter, annual screen maintenance occurs at Roza Diversion Dam. During maintenance, water is not diverted into the Roza Canal, and instream flows increase. Coho salmon and a small number of fall chinook are spawning in this sub-reach at this time (mid-October through December). When maintenance is completed, the power diversion resumes, which reduces instream flow and has resulted in dewatering of redds depending on the timing of maintenance relative to spawning activity and magnitude of power diversion.

Water Quality

The Yakima Project creates no known water quality concerns in this reach when maintenance and operation procedures are carried out properly. In December 2000, turbidity increased significantly as the Roza Pool was drained due to a change in standard protocols.

6.2.3.2 Naches River Confluence to the Roza Power Plant Return (Roza Wasteway #2)

Diversion Dams

Project diversion dams are not located in this reach.

Flow Regulation

This reach borders the city of Yakima, and the west side is generally confined by a dike. This reach is 3 miles long and contains some side channels, islands, and backwater areas. This sub-reach is known to support coho and some fall chinook spawning, and also provides rearing habitat for all salmonid species. A hydromet gage is not located in this reach and, therefore, flows in this sub-reach are deduced by looking at the hydrographs for the Naches River at Naches (NACW) and the Yakima River near Umtanum (UMTW). The inflow of water from the Naches River moderates fluctuations evident in the reach directly upstream. During the non-irrigation season (mid-October to mid-March), flows in the Naches River are substantially lower than unregulated because water is being stored in Rimrock Reservoir and flows on the Tieton River are very low as was discussed previously. Flows in the Yakima River are also quite a bit lower than unregulated due to storage operations in the reservoirs on the Yakima side. The winter low flow problem is exacerbated by the water diverted at Roza to generate power. The lower flows through the winter dewater side channels that juvenile coho salmon once inhabited.

Spring runoff flows (peak flows) are much lower than unregulated flows in this sub-reach because those on the Naches River are reduced 25-30 percent (again primarily because of reduced flows on the Tieton) and because peak flows on the Yakima arm are reduced (look at the Umtanum hydrograph). In this sub-reach the peak flows are further diminished because RID is withdrawing irrigation water and power is being generated. This affects emigration cues for smolts.

In late June, after the runoff, the situation reverses as conveyance of irrigation water drives flows to levels that are much above unregulated in the upper Yakima River. However, in this sub-reach, the diversion of water at Roza for both irrigation and power production lessens the effect considerably and one would expect the difference between regulated and unregulated flow conditions to narrow significantly. Since water is still being delivered to downstream irrigation districts, including the two biggest districts in the basin (Sunnyside and Wapato), summer flows would still be substantially higher than unregulated flows. This is unnatural, but the effects to fish are unknown.

This sub-reach is the first one on the Yakima side of the basin which does not have the huge change in flow associated with flip-flop since it is below the Naches/Yakima confluence. During the transition period flows are generally a little higher and may fluctuate more, but once the transition is complete the flows remain fairly stable.

Generally in November, maintenance of the Roza Diversion Dam fish protection facilities, Roza Canal, and Roza Power Plant occur and water is not diverted into the canal increasing flows in the river. When maintenance is complete, diversions begin and are believed to result in dewatering redds of coho salmon, which are known to spawn in the side channels between Selah to Union Gap.

Water Quality

Turbidity increases in early September as the project transitions to flip-flop. This may temporarily disrupt feeding of rearing fish. Otherwise, water quality in this reach does not appear to be impaired by project operations.

6.2.3.3 Roza Power Plant Return (Roza Wasteway #2) to Wapato Diversion Dam

Diversion Dams

Project diversion dams are not located in this reach.

Flow Regulation

Regulated flows in this reach are represented by the hydromet gage YRTW - Yakima River at Terrace Heights Bridge (see figure on page 6-50). No unregulated flow is estimated in this 7.6 mile long reach.

Summer and fall flows in this reach are higher than unregulated as a result of storage releases to supply water to Wapato and Sunnyside Diversion Dams. Under this operational scenario, the many side channels within this reach are connected to the river, offering access to relatively good quality rearing habitat. However, as flows recede at the end of the irrigation season, many of these side channels dry up, potentially stranding fish. Flows during the spring are also lower than unregulated flows, potentially disrupting emigration.

Another concern with flows in this reach is the effect of return flows from the Roza Power Plant. Adult salmon are attracted to the Roza Power Plant return flows at Roza Wasteway #2. The canal is screened at its confluence with the main stem Yakima River to prevent migrating adults from entering while still allowing smaller fish passage. In December 2000, a few hundred coho salmon were observed holding in the pool at the Yakima River and Roza Wasteway #2 confluence. A few attempts were made to drive fish away from this area with moderate success. This was the first year that this problem has been documented with the coho salmon.

Water Quality

This reach also experiences an increase in turbidity during the transition to flip-flop operation and feeding of rearing fish may temporarily be disrupted. Additionally, Moxee Drain, a Roza Canal drain, enters this reach and compromises water quality.

6.2.3.4 Wapato Diversion Dam to Sunnyside Diversion Dam

Diversion Dams

Wapato Diversion Dam -

Fish ladders, screens, and bypass at Wapato Diversion Dam meet the current NMFS standards for fish protection. However, passage of adults is of some concern. Hockersmith et al., (1995) identified passage delays at all project diversion dams by radio tagging steelhead. They measured the median number of days it took adult steelhead to pass Wapato Diversion Dam was 6.9 ($N = 19$) and Sunnyside Diversion Dam was 0.4 ($N = 40$). This indicates ongoing passage problems associated with the Wapato Diversion Dam. Additionally, the Wapato Diversion Dam tailwater is the most productive salmon fishing area for tribal members, most likely because of the delay and concentration of fish. Predation by gulls and northern pikeminnow has been identified as a potential source of fish loss at the Wapato main canal fish screen bypass return.

Flow Regulation

In this short reach (1.9 miles), up to 2,200 cfs is diverted at the Wapato Diversion Dam or nearly 50 percent of the water entering this reach when the system is under storage control. This withdrawal moves this reach closer to the expected natural flow at this time of year.

There is no hydromet gage located in this reach; the estimated unregulated flow is the same as the calculated unregulated flow at Parker (no tributary inflow). During the non-irrigation season, the effects of the Yakima Project are believed to be similar to those experienced in the downstream reach, Sunnyside Diversion Dam to Marion Drain, where a hydromet gage is located (PARW) and differences between regulated flow and estimated unregulated are calculated.

Water Quality

The Yakima Project creates no known water quality concerns in this reach.

6.2.3.5 Sunnyside Diversion Dam to Marion Drain

Diversion Dams

Sunnyside Diversion Dam -

Fish ladders, screens, and juvenile fish bypass at Sunnyside Dam meet the current NMFS standards for fish protection. This includes times when flows are less than 400 cfs and the ladder operation is modified (see section 5.4). When flows approaching the dam are less than 400 cfs a gravel bar is exposed in the forebay. This is not believed to impact fish passage, but it should be monitored.

Additionally, a problem exists as the canal is shutdown for the season. Juvenile and adult fish, including salmonids, are stranded in pools just upstream of the screens. Water does not completely drain in the area and standing pools of water remain. In 1998, approximately 15 adult salmon and many juvenile salmonids were salvaged. The salvage process can be difficult and juveniles may be harmed or could die during the process. Non-target taxa are left in the standing pools. Predation by gulls and northern pikeminnow has been identified as a source of fish loss at the bypass return.

Flow Regulation

The reach between the Sunnyside Diversion Dam and Marion Drain is approximately 21.2 miles long and is considered one of the most structurally complex and diverse sections of the Yakima River. For most of this reach Interstate 82 defines the north and east floodplain boundary, whereas the south-west side of the river is in a semi-unconstrained state. Numerous side channels, braids, and backwater areas exist. Larger project agricultural drains enter into the river in this reach and increase the flow, particularly during the irrigation season. This reach is considered one of the main areas where the anadromous salmonid pre-smolts spend the winter before migrating out of the Yakima River. It is also an important area for fall chinook and coho spawning, and adult steelhead holding through the winter. The Sunnyside Diversion Dam is the main control point in the river system for the project, and since 1995, the flow below the dam has been managed for a target based on TWSA. The target flow can range from 300 to 600 cfs during the irrigation season depending on the water supply for that year. Flows are managed to meet the specific target during the irrigation season.

The annual hydrograph for the Parker gage (PARW), located just below the Sunnyside Diversion Dam is displayed in figures on pages 6-52 & 53. In the fall and winter during the non-irrigation season, flows display the natural pattern, but are reduced in magnitude by nearly a third. During the late winter and early spring, anadromous salmonid smolts are moving into this area for rearing, and fall chinook and coho fry are beginning to emerge. Reduced flows limit the habitat availability at a time of high anadromous salmonid abundance. Spring peak flows are also substantially reduced (50+%) affecting emigration cues for anadromous salmonid smolts and limiting rearing habitat. During the irrigation season flows are low, less than half of unregulated flows, and impact rearing habit for salmonids and other native fish particularly. Flow regulation also resulted in an earlier onset and longer duration of this low flow period also. At Granger irrigation return water enters the river (35-60 cfs in the summer).

Flow fluctuations from river operations upstream are amplified below the Sunnyside Diversion Dam (figure 6-4). At times, the hourly flow fluctuation can exceed 20 percent of the base flow, which may be great enough to cause stranding of juvenile steelhead, dewatering of invertebrate habitat, and increase water temperatures to lethal levels in some areas (figure 6-5). Inflows below the Sunnyside Diversion Dam gradually dampen the fluctuations so that, by Grandview, fluctuations are negligible (figure 6-6).

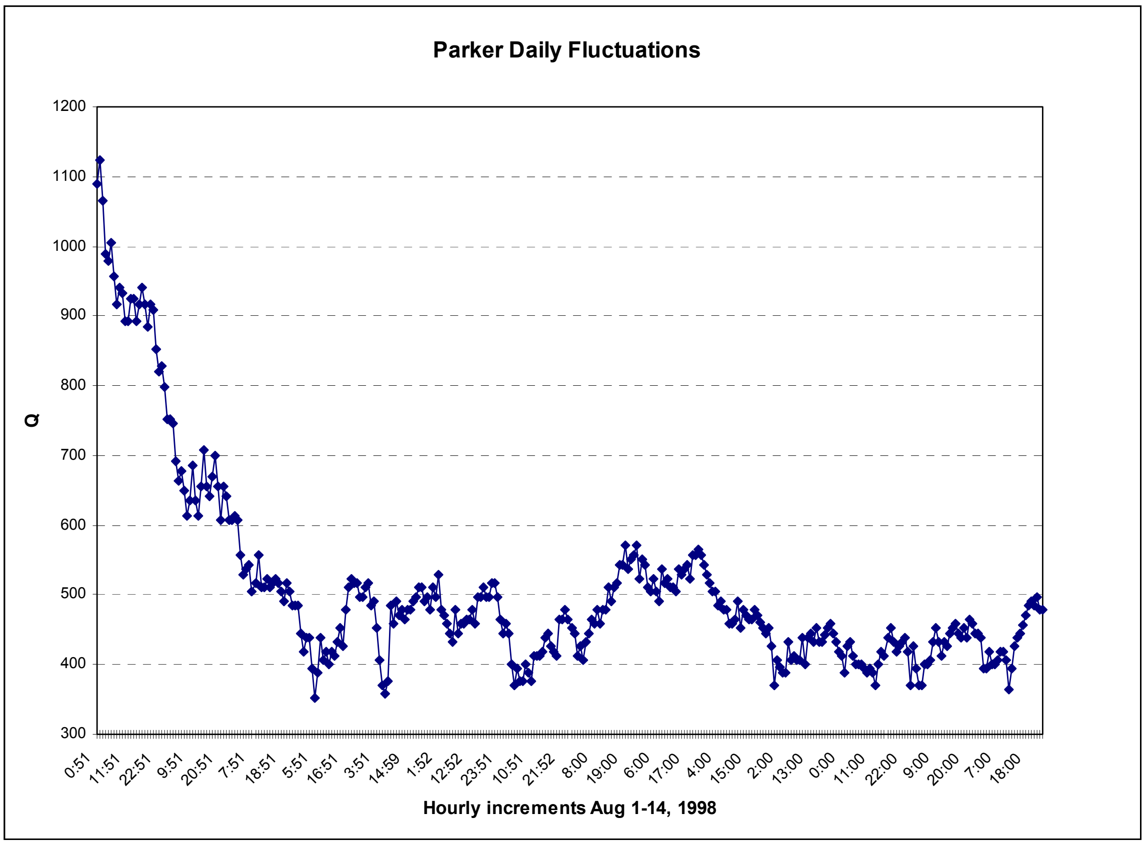


Figure 6-4. Hourly flows at the Parker Gage for the period August 1-14, 1998.

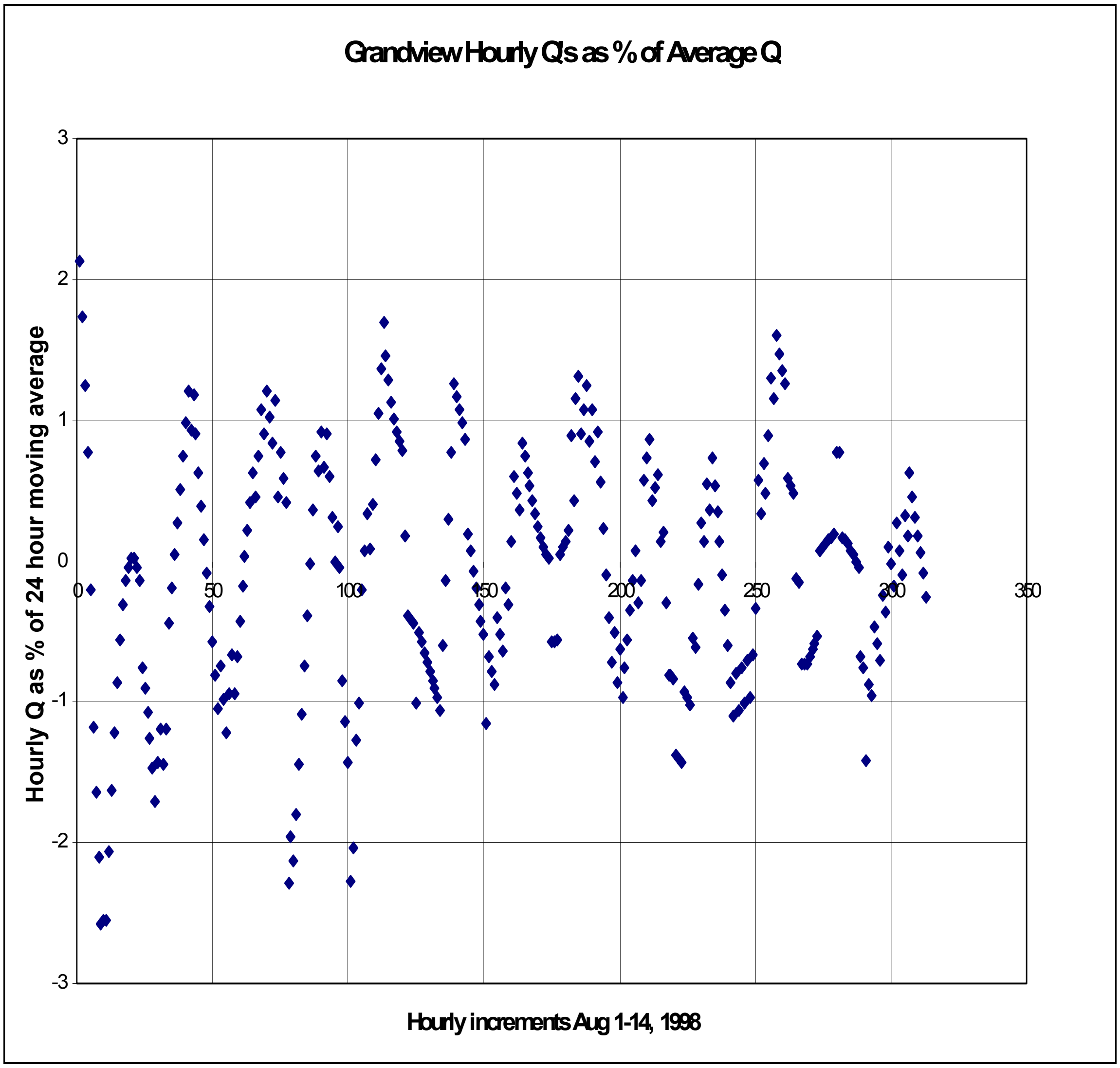


Figure 6-5. Fluctuations at Grandview Gage measured as percent deviation of hourly discharge from the running 24 hour average discharge.

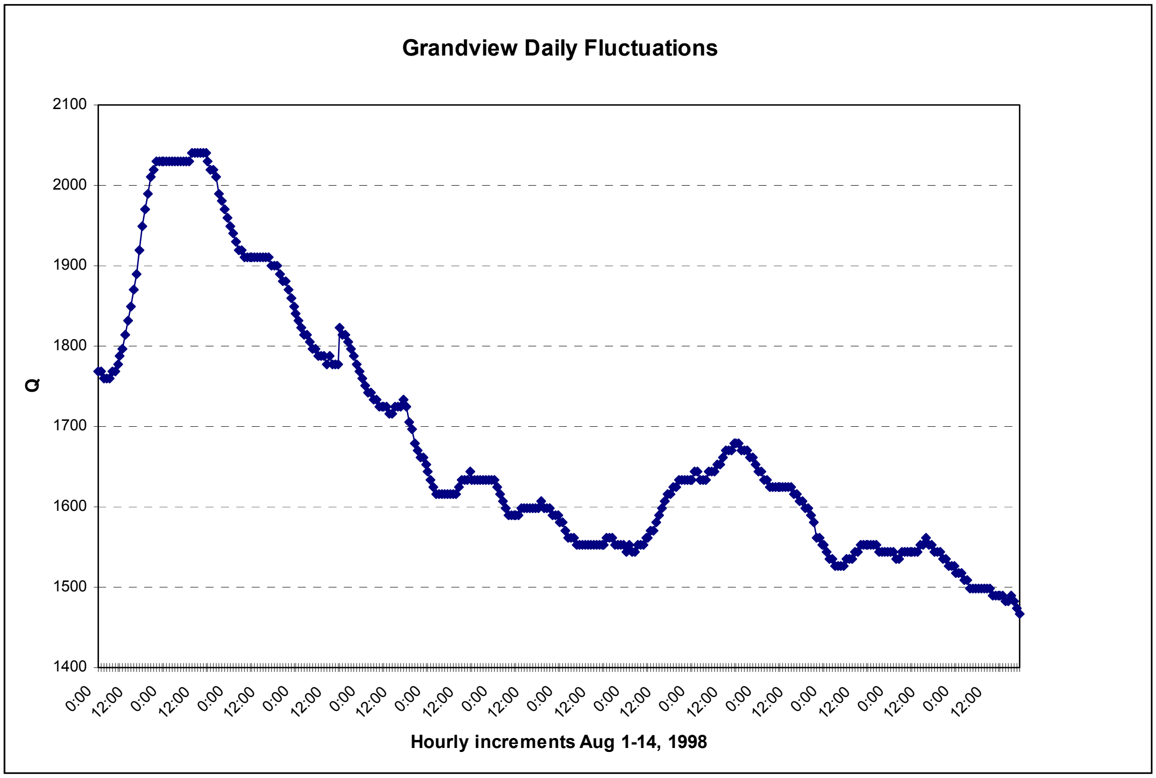


Figure 6-6. Hourly flows at the Grandview Gage for the period of August 1-14, 1998.

Juvenile salmonids have been observed in the lower end of Granger Drain, but a series of culverts prevents passage a short distance upstream (Pat Monk, consulting fisheries biologist for Yakima Basin Joint Board, personal communication, 2001). It is unknown whether salmonids inhabit East Toppenish Drain or other drains in this reach.

Water Quality

This section of the Yakima River is listed on the Washington State's 303(d) list for violating several water quality parameters including: pesticides, PCBs, temperature, FC, pH, DO, and turbidity (Morace et al., 1999). Low river flows and agricultural return flows are a main source of degraded water quality. Pesticides and PCBs are lethal to fish and also bio-accumulate, and result in human consumption advisories for fish captured in this reach. Elevated water temperatures are lethal to salmonids and other cold water fish, and limit the amount of time this reach is suitable for salmonid rearing. In most years, the water temperatures get too warm to support salmonid rearing in this reach of the river during the summer months. However, groundwater inflows do provide some cool water refuges that provide some very limited rearing habitat for salmonids. High water temperatures and elevated pH can also exacerbate the effects of toxic chemicals and either stress fish, which may result in death from secondary causes, or kill them directly. Elevated turbidity indicates high sediment loading and results in the armoring of spawning gravel, siltation of redds, and decreased macro-invertebrate production. The high nutrient loading along with warmer water temperatures create habitat conditions more favorable to non-native species, some of which are predators upon anadromous salmonids. Recent improvements to farming practices have improved water quality in this reach, especially for turbidity and total suspended sediments. See section 6.1.1 for effects of water quality on fish.

6.2.3.6 Marion Drain to Prosser Dam (35.5 miles)

Diversion Dams

Project diversion dams are not located in this reach.

Flow Regulation

The upper 17 miles of this reach includes side channels, back water areas, and diverse habitat types. Satus and Toppenish Creeks enter in this reach, along with significant inflow from groundwater and drains. The downstream 18 miles are low gradient with a single meandering channel and lower habitat diversity. The flows are represented by the Grandview gage (YVGW), approximately midway through the reach. Unregulated discharge is not estimated at this site. It is believed that flows measured at the Parker gage are similar in pattern here; however, substantial return flow (around 700 cfs minimum) enters this reach in the lower portion. The larger drains include Marion Drain (RM 82.6), Coulee Drain (RM 77), South Drain (RM 69.3), DID #7 (65.1), Sulphur Creek Wasteway (RM 61), and Satus Drain (RM 60.2).

Marion Drain is the major drain for WIP and flows range from approximately 500 cfs during the irrigation season to 200 cfs during the winter. Fall chinook salmon naturally reproduce in Marion Drain. The drain parallels Toppenish Creek and is straight, deeply incised, and lacks riparian vegetation.

Sulphur Creek Wasteway enters the Yakima River from the north and is a combined wasteway for the RID and the SVID. Several county drainage districts and the city of Sunnyside's storm water system and sewage treatment plant drain into Sulphur Creek Wasteway. The creek is channelized and considered poor habitat. Today, year-round flows attract salmonids and spawning and rearing of salmonids have been observed. However, it is unknown whether the rearing fish were successfully produced in this system or if they produced elsewhere and entered for rearing only. It is believed that salmon entering this creek are falsely attracted. Hatchery coho are released at sites above Roza Diversion Dam; however, based on radio tagging studies conducted in 2000, few coho passed Roza Diversion Dam and most were observed at Roza Project irrigation returns (Sulphur Creek Wasteway and Roza Power Plant return).

It is likely that other drains provide seasonal rearing habitat for salmonids and other native fish. Adult salmonids may also be attracted to these drains and spawn with unknown success.

Water Quality

The water quality problems in this reach are essentially the same or worse than the reach immediately upstream (Sunnyside Diversion Dam to Marion Drain) because of the numerous large irrigation return drains entering this reach.

This section of the Yakima River is listed on the Washington State's 303(d) list for violating several water quality parameters including: pesticides, PCB, temperature, FC, pH, DO, and turbidity (Morace et al., 1999). Low river flows and agricultural return flows are a main source of compromised water quality. Pesticides and PCBs are lethal to fish and also bio-accumulate, and result in consumption advisories for fish captured in this reach. Elevated water temperatures are lethal to salmonids and other cold water fish, and limit the amount of time this reach is suitable for salmonid rearing. In most years, the water temperatures get too warm to support salmonid rearing in this reach of the river during the summer months. However, groundwater inflows do provide some cool water refuges that provide some very limited rearing habitat for salmonids. High water temperatures can also exacerbate the effects of toxic chemicals and either stress fish, which may result in death from secondary causes, or kill them. Elevated pH can also result in death or stress which can eventually lead to death from secondary causes. Excessively high or low pH exacerbates the effects of toxic chemicals. Elevated turbidity indicates high sediment loading and results in the armoring of spawning gravel, siltation of redds, and decreased macro-invertebrate production. The high nutrient loading along with warmer water temperatures create habitat conditions more favorable to non-native species, some of which are predators upon anadromous salmonids. Recent improvements to farming practices have improved water quality in this reach especially for turbidity. See section 6.1.1 for effects of water quality on fish.

6.2.4 Lower Yakima River

This reach is separated into two sub-reaches and storage dams are not present in either.

6.2.4.1 Prosser Diversion Dam to Chandler Canal Return

Diversion Dams

Prosser Diversion Dam -

Fish protection facilities at Prosser Diversion Dam meet NMFS criteria; however, there are still serious concerns associated with passage at this dam. Downstream migrant mortality in the Chandler Canal and in the Chandler Smolt Enumeration Facility is generally 10 percent (Bruce Watson, Yakama Nation, personal communication) and can be much higher during certain times of the year. Data provided by the NMFS PIT-tag study of spring chinook smolts in 1992, indicated that in the latter half of May, at relatively high river temperatures (16 to 22 °C), smolt mortality in the upper canal (between the head gates and the fish diversion screens) could be in the order of 40 percent (Sanford and Ruehle, 1996). Significant loss of smolts was also associated with passage through the Smolt Enumeration Facility. Though no comparable data have been presented for other anadromous species, it is reasonable to suspect that similar mortality rates occur for them. McMichael and Johnson (2001) suggested that loss of fish in the canal likely resulted from a combination of factors, such as damaged seals and predation.

Another major concern with this facility occurs in the fall of each year when the canal is dewatered for screen inspection and Chandler Power Plant maintenance. Adult fish, including numerous salmonids, are entrained in the canal and stranded between the point of diversion and the trashracks. Adult fish are unable to pass through the trashracks. Smaller fish are able to pass through the trashracks and are returned to the river via a 30-inch drain pipe. In 1998, about 200 adult fall chinook and 2 steelhead were salvaged during the dewatering process that occurred prior to screen maintenance; no bull trout were found. Other fishes (e.g., northern pikeminnow, suckers) are also stranded, but are not salvaged. The Yakama Nation coordinates with Reclamation on canal drawdown so they can use stranded adult salmon as broodstock for their hatchery propagation program.

Adult passage may be compromised as LWD builds up on the rock ledge apron below the dam. This potentially blocks the entrances and exits to the fish ladders. The center ladder is most susceptible to this occurrence. Although a standard protocol for timing of debris removal is not established, it is generally removed when a large amount is present.

Hockersmith et al., (1995) determined passage delay of radio tagged steelhead at Prosser Dam ranged from 0.1 to 128.3 days for 100 fish (median 5.9 days). The median days to pass was higher than all other project diversions except Wapato (6.9). As water temperatures decreased, fish passage also decreased.

Predation at the fish bypass return has warranted enough concern to have two studies evaluating it. The WDFW's Ecological Interaction Team is evaluating fish predation in the lower river and considers the Chandler Canal fish bypass return to be one of the "hot spots" for predation on salmonids. A fish predation index or percent mortality has yet to be developed for this site. In the 1998 annual report, Pearsons (1998) estimated 1.1 percent of the salmon passing through the Chandler Canal fish bypass return were consumed by avian predators.

Flow Regulation

Flows from Prosser Diversion Dam to the Chandler Canal return (11.3 miles) are depicted by the hydromet station (YRPW). This may be a major fall chinook spawning area and rearing area for all anadromous species. Unregulated discharge is not available for this site, therefore, comparisons are made to the unregulated flow pattern at Parker (PARW) understanding the difference in magnitude (i.e., larger volumes downstream). At Prosser Diversion Dam up to 1,500 cfs is diverted into the Chandler Canal which serves the Kennewick Irrigation District (KID) and the Chandler Power Plant. Power water (about 1,175 cfs) returns to the river approximately 11 miles downstream and the remaining 325 cfs is used to serve KID's irrigation needs. The bypass reach suffers from severely low flows in the summer and early fall. This is a result of diversions at Prosser Diversion Dam and Title XII target flows at PARW and YRPW. This flow regime creates conditions favorable to non-salmonid fish reproduction and survival (lower, more stable flows; warmer, nutrient rich water). Non-salmonids, both native and introduced species, compete for food and habitat and prey on juvenile salmonids.

After the irrigation season, flow patterns more closely match that of the unregulated hydrograph, but at a much reduced magnitude. Diversion for power continues at Prosser Diversion Dam, but can be partially subordinated to protect fish resources. In the fall, annual maintenance is performed on the Chandler screening facility and Power Plant. These activities usually require about 2 weeks. Unfortunately, maintenance typically occurs when fall chinook are at the peak of their spawning activity and some coho are spawning in the reach as well. When the canal is shutdown and dewatered, the water which had been diverted for power production remains in the river and instream flows increase significantly, and many salmon excavate their redds at the elevated flow level. When maintenance is completed and the power diversion resumes, instream flows are reduced and redds can, and have been, dewatered. In recent years, Reclamation, after consultation with SOAC and their environmental staff, has attempted to coordinate Chandler maintenance to reduce or eliminate the effects on spawning salmon. The effort has been successful for the most part, but some problems remain. Redds are usually incubated at a lower flow which affects the hydrology within the redd.

In the spring, regulated flow is significantly lower than estimated unregulated to the point where a spring peak flow may be nonexistent, depending on the water supply. This affects smolt emigration to the Columbia River, especially in drought years. Movement is stalled and smolts may remain in this reach into the summer when conditions threaten survival. Water temperatures are elevated, water quality is compromised, and predator abundance is higher (smallmouth bass and channel catfish migrate from the Columbia River). Additionally, the amount of habitat is decreasing at a time when more smolts are using this reach.

Spring and Snipes Creeks enter into this reach and serve as drains for the Sunnyside and Roza Canals respectively. These streams were once ephemeral, but now flow year-round with low flow periods in February and March prior to the start of the irrigation season. Adult and juvenile salmonids have been observed in these creeks/wasteways (Pat Monk, consulting fisheries biologist for Yakima Board of Joint Control, personal communication, 2001). Adult salmonid spawning poses some concern because these fish may be responding to false attraction flows. It is unknown if habitat conditions are conducive to successful reproduction.

Water Quality

Water quality entering this reach is already of compromised quality. The additional withdrawal at Prosser Diversion Dam has minimal or no effect on water quality (Carrol and Joy, 2001). These investigations also found that irrigation returns in this reach do not appear to further compromise water quality. This reach experiences the same effects as those immediately upstream. The high water temperatures delay the migration of adult fall chinook from the Columbia River into the Yakima River, and combined with low flows create unsuitable conditions for rearing anadromous salmonids in the Yakima River below Prosser Dam from July to September.

6.2.4.2 Chandler Canal Return to Confluence With Columbia River (35.8 miles)

Diversion Dams

Wanawish Dam -

The biggest concern with Wanawish Diversion Dam, a non-Reclamation operated facility, is predation. This has been identified as a "hot spot" for fish and avian predation on salmonids. In the 1998 annual report, Pearsons (1998) estimated 1.7 percent of the juvenile salmon passing Wanawish Diversion Dam were consumed by avian predators. Predation loss to fish is significant and a study is being conducted to develop a predation index for this site. A large number of smallmouth bass congregate below the dam in the spring when salmonids are emigrating. It is believed that smallmouth bass and other predator fish, such as channel catfish and northern pikeminnow consume the disoriented salmonids as they pass over the dam.

The ladders, fish screens, and bypass were designed to meet NMFS criteria.

Flow Regulation

Flows in this reach are measured near KIOW and unregulated flow is not calculated here. Flow improves as Chandler Power Plant water returns, but is still lower than the estimated unregulated flow, particularly in the spring and summer. These low flows affect emigration cues and likely increase predation as a large concentration of non-native predator (bass and catfish) inhabit this reach. These non-native fish benefit from the lower more stable flows which are nutrient rich and warmer. An additional withdrawal of approximately 300 cfs at Wanawish Diversion Dam (Columbia Irrigation District 220 and Richland Canal 80 cfs) exacerbates the low flow problems. In late summer and early fall, low flows and resultant warm temperatures may delay migration of steelhead, fall chinook, and coho salmon into the Yakima River. Fortunately, salmon spawning in this reach are not affected by screen, dam, and canal maintenance at Prosser Diversion Dam or in Chandler Canal. Flows in the late fall and most of the winter are lower than expected due to reservoir storage which reduces the amount of available habitat.

Water Quality

Water quality entering this reach is already of compromised quality. The additional withdrawal at Wanawish Diversion Dam has minimal or no effect on water quality (Carrol and Joy, 2001). Minor irrigation returns in this reach do not appear to further compromise water quality. This reach experiences the same effects as those immediately upstream. The high water temperatures also delay the migration timing of adult fall chinook from the Columbia River into the Yakima River.

6.2.5 Bumping River

Storage Dams

Bumping Dam and Reservoir -

The effects of Bumping Dam and Reservoir on the fishery resource were generally described at the beginning of this section. Approximately 1 mile of lotic habitat is inundated by this reservoir, substantially less than other project reservoirs due to its small size and the narrow range of fluctuation in the reservoir pool. When Bumping Reservoir level is very low, it is possible for fish to move freely downstream through the outlet works because there is little head difference at the outlet structure. However, there has been no documentation of fish migrating from the reservoir through the outlet works. It also does not seem likely that fish can migrate from the river to the reservoir when reservoir levels are low because of the high water velocity barrier in the tailrace flume. Little is known about passage conditions on Deep Creek, the primary bull trout spawning tributary to Bumping Lake. WDFW (1998) reported that low flows in the creek combined with low reservoir elevation can limit access to some spawning areas and that rearing juveniles have become stranded in dry channels. These low flow conditions have been observed about 1 mile above the mouth of Deep Creek (Eric Anderson, WDFW, Yakima, personal communication, 1999), but low reservoir elevations do not effect this low flow condition.

Diversion Dams

No project diversion dams are located in this reach.

Flow Regulation

The Bumping River is 16.6 miles long from the dam to its confluence with the Little Naches River. Spring chinook salmon spawn in the river and it is possible that steelhead and bull trout do as well, although this has not been documented (these species have been found in the American River which enters the Bumping 3.5 miles above the Little Naches confluence). Because of the reservoir's small size, water releases from Bumping Reservoir are more normative than larger storage reservoirs (see figure on page 6-40). Regulated releases are lower from April through June as water is being stored and higher flows result in July through October to meet irrigation demands. The most critical flow problem on the Bumping River concerns the issue of incubation flows. Spring chinook salmon spawn in September when, as a direct result of flip-flop, regulated flows in the Bumping are at least twice the level of those which would occur under unregulated conditions. This results in a large percentage of redds being established near the margins of the river and requires incubation flows at, or very near, those provided for spawning to ensure that these redds are not dewatered. In most years this is not a problem as Bumping Reservoir is relatively small and refills quickly in a normal or wet winter. In dry and/or abnormally cold winters however, it can become impossible to provide protective incubation flows. Such was the case in the winter of 2000/2001. Over 275 spring chinook redds were constructed on the Bumping in September 2000, at a flow of 200 cfs. By mid-November it became obvious that Reclamation would be unable to provide adequate incubation flows and by the first of the year the flow release from Bumping Reservoir was only 70 cfs, the inflow to the reservoir. Although it is likely redds were dewatered, production of spring chinook was documented in the river (Pat Monk, fish consultant for Yakima Basin Joint Board, personal communication 2001).

Water Quality

The Yakima Project creates no water quality concerns in this reach.

6.2.6 Upper Naches River

Storage Dams

Storage dams are not present in this reach.

Diversion Dams

No project diversion dams are located in this reach.

Flow Regulation

The upper Naches River reach is 27 miles long extending from the confluence of the Bumping and Little Naches Rivers to the confluence of the Naches and Tieton Rivers. Spring chinook salmon and steelhead are known to spawn and rear in the reach, and bull trout are present as well. The extent to which the latter species uses the reach for various life stage activities is unknown, but fluvial bull trout spawn in tributaries of the Naches River (e.g., American River, Rattlesnake Creek, Crow Creek) and have been harvested (illegally) in the main stem Naches as recently as last year. Flows in this reach are represented by the hydromet gage CLFW (Naches River at Cliffdell, figure on page 6-42). The regulated hydrograph of the Bumping River closely resembles unregulated conditions, more so than any other regulated reach in the basin. Alterations to the unregulated flow as a result of Bumping Reservoir releases are evident, but relatively insignificant.

Water Quality

The Yakima Project creates no water quality concerns in this reach.

6.2.7 Tieton River

Storage Dams

Rimrock Reservoir and Tieton Dam -

Tieton Dam presents the complete set of problems associated with storage dams. A much larger amount of lotic habitat was inundated with the construction of Rimrock Reservoir because it was not associated with a natural lake. McAllister Meadows, which was inundated, was considered high quality habitat for spring chinook, coho, steelhead, and bull trout.

Unique concerns associated with Rimrock Reservoir and the Tieton Dam are passage into and out of the South Fork of the Tieton River and entrainment in the outlet works, both of which are affected by Reclamation operations. On the South Fork of the Tieton River, a seasonally submerged falls creates a migration barrier at times. This falls is located near the main Tieton River Road where it intersects the South Fork Tieton River. This falls is a result of realigning the river so a bridge could be built over the South Fork Tieton River. The new channel went over a cliff and creates a barrier falls when the reservoir recedes. This falls is submerged when Rimrock Reservoir is at full pool (2926 feet above mean sea level [msl]; reservoir volume 198,000 acre-feet). The elevation at the top of the falls is approximately 2899 feet msl (127,000 acre-feet) and when reservoir levels drop below that, passage problems arise for all species. In most years, because of the run timing of bull trout in the South Fork Tieton and pre flip-flop reservoir operations that hold the reservoir elevation high (above 2899 feet msl), this barrier most likely affects this species as they move back to Rimrock Lake when the falls can exceed a 20-foot drop. On October 10, 1999, Scott Craig of the FWS, Lacey, Washington found two dead bull trout and two dead suckers (*Catostomus* spp) at Rimrock Reservoir below this falls (2868.67 msl, 81,761.88 acre-feet).

Although every reservoir experiences severe drawdown, a minimum conservation pool (historical lake bed) still remains at all the reservoirs except Rimrock Reservoir, for which a minimum pool level has not been established. Rimrock Lake has not been drafted below 21,988 acre-feet (end-of-month September) or 10,730 acre-feet (end-of-month October) since 1987. Fish can be entrained through the outlet works, which is exacerbated at lower pool levels. It has been documented that kokanee were killed, as a result of, or while passing through the outlet works at Tieton Dam (Mongillo and Faulconer, 1980). It is also possible that bull trout could be directly harmed in going through the outlet structure. Studies began in September 2000, to evaluate bull trout entrainment into the Tieton River. Preliminary information identified that one sub-adult bull trout was captured in fyke nets positioned below the dam outlet. The range of reservoir levels sampled was 165,718 acre-feet to 85,996 acre-feet, thus the gravity of this problem under more severe conditions remains unknown.

Because Rimrock Dam was built on a river and not an existing lake, gravel recruitment has been greatly impacted in the Tieton River. The dam has not only affected the availability of gravels and cobbles suitable for spawning, but has also affected the channel form and pattern. The existing channel is degraded and incised resulting in a loss of habitat diversity.

Clear Lake Dam and Reservoir -

Clear Lake Dam does not provide adequate upstream passage for bull trout migrating into the North Fork Tieton. The fish ladder was constructed in the early 1990s and evaluated for one season (mid-August through October) in 1994. Researchers found that whitefish and small rainbow trout were able to negotiate the upper portion of the ladder, but bull trout were never trapped at the top of the ladder (Paul James, Central Washington State University, personal communication, 1998). It appeared that fish were attracted to the base of the dam, rather than to the ladder entrance, which is isolated from the dam and reservoir outlet works. This may have been because flows down the ladder were relatively warm due to the surface diversion, insufficient attraction flows, or both. Further investigations should be conducted to determine the efficiency of the ladder. Routine maintenance of the ladder is also lacking and needs to be addressed by project fish facility personnel.

Diversion Dams

Yakima-Tieton Diversion Dam -

The Yakima-Tieton Diversion Dam was rebuilt in 1990, to facilitate river rafters going over the dam and to provide fish passage. The fish passage facility is a chute type structure with stop-log guides to create a pool and step type facility. It is difficult to manage the stop-logs and fish have been observed jumping at the dam. The ladder does not meet current passage standards and Reclamation is working with the Fish Passage Technical Work Group to address this issue. Fish screens and juvenile bypass facilities meet current standards. However, during major rain events the screens at this diversion tend to clog up quickly impeding their performance.

Routine operation of this diversion results in little fluctuations to the river flow downstream because of coordination of diversions and releases from Tieton Dam. Flow reductions from Rimrock Dam are requested for maintenance at Yakima-Tieton Diversion Dam during the irrigation season. This reduction in flow is undesirable, and fortunately, does not happen often.

Flow Regulation

Flows in the Tieton River are measured by hydromet gages at Rimrock Reservoir (RIM) and downstream of the Yakima-Tieton Diversion Dam (TICW). This reach is 21 miles long and has no minimum flow standard. The flow regime of the Tieton River represents the most extreme alterations to the natural hydrograph of any location in the basin (see figures on pages 6-44 & 45). Flows from mid-October to July are profoundly below those that would occur under unregulated conditions. Winter flows on the Tieton River are frequently less than 30 cfs for extended periods and have on numerous occasions dropped below 20 cfs. Peak flows during the spring runoff are substantially reduced, approximately 33 percent, which reduces emigration cues for salmonids rearing in the middle and lower Yakima River reaches. With the inception of flip-flop in early September, releases from Tieton Dam increase dramatically from about 650 cfs to over 2,000 cfs until they are abruptly reduced at the end of the irrigation season in mid-October. During this time, when unregulated flows would typically be at their lowest levels of the year, Tieton River flows are up to five times higher than would occur naturally. These peak flows are nearly twice the magnitude of those which would occur under unregulated conditions during the runoff period in May and June. The physical and biological effects of the regulated flow regime on the Tieton River have been more than significant. Anadromous and resident salmonid reproduction has not been observed for decades in the river. The aquatic invertebrate community is depressed, the result primarily of stranding which occurs when invertebrate habitat is dewatered in the winter. Spawning gravels have been washed downstream with no source for replacement. The lack of bedload recruitment from above the dam has affected the channel morphology as well with a resultant decline in habitat complexity.

Flows from Rimrock Reservoir tend to fluctuate more when the reservoir is at or near full capacity. Rain and wind (which pushes water over the spillway) are generally the causes for the fluctuations. Releases through the main gates have been made to avoid water passing over the spillway and tend to create a more abrupt hydrograph (quicker increases and decreases to the hydrograph).

Water Quality

Water temperature may be a concern in the Tieton River below the dam. Summer releases appear to be cooler than expected when compared to the onset of flip-flop operations, when the water temperature increases by approximately 5 °C (figure 6-7) before declining. This can disrupt spawning of anadromous salmonids and bull trout and effect feeding ecology of rearing juveniles. Additionally, this may temporarily increase water temperature in the lower Yakima River because of the large amount of water being released, and delay migration of adult fall chinook salmon and steelhead into the basin. These temperature concerns are speculative because it is based on only 1 year of data, but it suggests that further investigation is warranted. Other water quality parameters have not been measured during flip-flop.

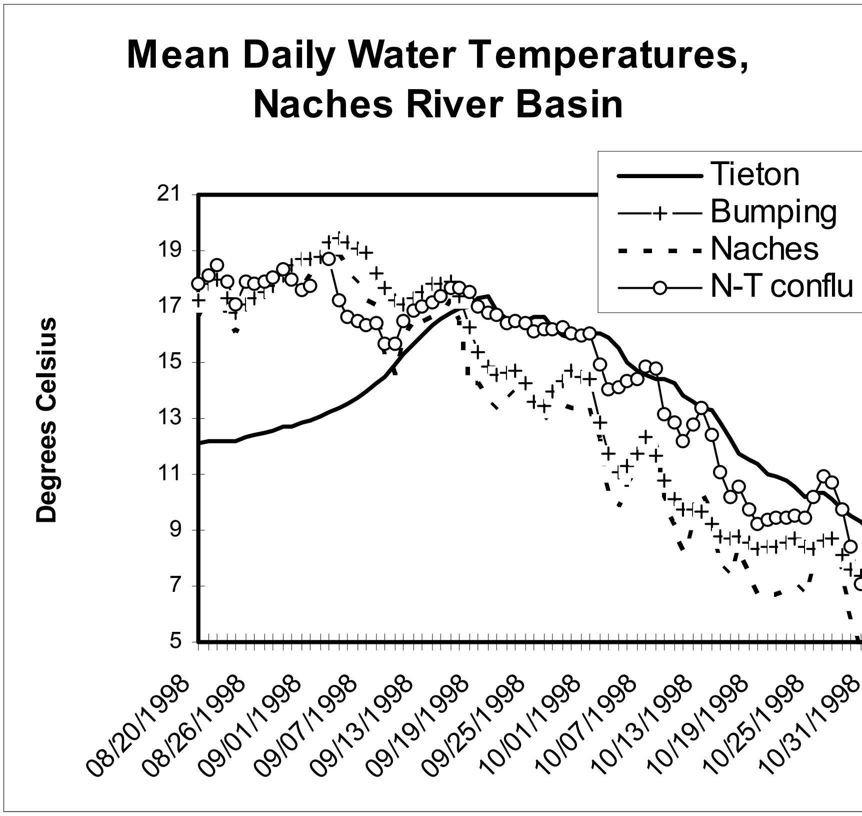


Figure 6-7. Water temperature (degrees Celsius) from August 20 through October 29, 1998, on the Tieton, Bumping Naches (upstream of confluence with Tieton) and Naches (downstream of confluence with Tieton) Rivers. (Unpublished data, Pat Monk, consultant/fisheries biologist for Yakima Basin Joint Board.)

6.2.8 Lower Naches River

Storage Dams

Storage dams are not present in this reach.

Diversion Dams

Wapatox Diversion Dam -

The Wapatox Diversion Dam, a non-project facility, was built by Pacific Power and Light and is now owned by Scottish Power. The existing concrete dam was constructed in 1978, with a pool and weir fishway. The upstream fish passage facility has been identified as a potential problem at certain flows. Spring chinook have been observed jumping at the dam and exhibiting possible delays in crossing the dam. The NMFS radio-telemetry study for steelhead did not indicate a problem for steelhead at this site (Hockersmith et al., 1995). The original diversion fish screens and bypass were replaced in 1993 with a modern facility.

Flows are rarely altered for maintenance which usually occurs during lower flows. Relatively stable power diversions mean that diversion-related flow fluctuations are not a major concern below this dam.

Naches Cowiche Diversion Dam -

Naches-Cowiche Diversion Dam, a non-Reclamation operated facility, at Naches RM 3.6, is a low head structure of approximately 6 feet. Salmon and steelhead can leap and swim over the structure at medium to high flows. A fish ladder was constructed in 1987, which meets NMFS criteria. The ladder is being modified to enhance the exit of the ladder and supply additional auxiliary water at the entrance. The fish screens and bypass present no problems to fish.

When conducting maintenance or installing flashboards, the irrigation district coordinates with Reclamation so flows can be reduced to provide a safe working environment. These procedures do not occur that often and are considered of minimal consequence to fish.

Flow Regulation

This reach extends from the confluence of the Tieton River downstream to the confluence of the Yakima River and is 17 miles long. This is an important reach for rearing chinook, coho, and steelhead. An occasional bull trout is also observed. Flows in this reach are described using flow data collected at NACW - Naches River near Naches. The pattern of regulated flows in the lower Naches River generally follows the unregulated hydrograph except for the unnatural flow spike in September (see figures on pages 6-48 & 49), when high flows released from Tieton Dam for flip-flop more than quadruple the discharge. This abrupt and significant fluctuation is a cause for concern because juvenile fish can be displaced or stranded. All flows, except during flip-flop, are reduced in magnitude, but of particular concern is the reduction in the spring peak flow by nearly 25 to 30 percent, the result of water storage at Tieton Dam.

The other major flow impact to this reach is the Wapatox Diversion Dam at RM 17.1, that diverts water for hydropower production for PacifiCorp and irrigation. The diversion can reduce natural flows in this reach by as much as 300-450 cfs. Most of this water, less 50 cfs during irrigation season, is returned to the river at the hydropower plant outfall at RM 9.7. There is an approximate 8 mile reach of the Naches River that is affected. The project works closely with PacifiCorp to provide a minimum flow of 125 cfs over the diversion dam year-round. Downstream of the dam, flows can be much lower during the irrigation season due to downstream diversions. There are times during cold winters, and during dry summers, when the flows stay at or a little below the target. At a flow of 130 cfs, nearly all side channels are cut off or reduced to a trickle. At a flow of 630 cfs, the flow that would be present if water was not diverted for power generation, suitable flow was available to connect nearly all side channels (preliminary data, Steve Croci, FWS, Yakima, Washington, personal communication, 2000). Side channels appear to be preferred habitat for rearing juvenile salmonids in this reach (preliminary data, Steve Croci, FWS, Yakima, Washington, personal communication, November 2000). There are other non-Reclamation operated diversions below the Wapatox Diversion that also affect the low flows in this reach and in combination can withdraw a significant portion of the river when flows are near 125 cfs.

Water Quality

The main water quality concerns with this reach are in regards to water temperature from flip-flop operations and diversions at Wapatox Diversion Dam. As stated in the Tieton River reach, during flip-flop operations water temperatures increase by 5 degrees and are evident in this reach also (see figure 6-7). Water temperature increase below the Wapatox Diversion Dam during the summer when air temperatures are high and flows low is a major concern. Low flows occur because the project is holding back releases from Tieton Dam in preparation for flip-flop, and the numerous diversions, including Wapatox Diversion Dam, reduce flows below 125 cfs. Although the elevated water temperatures are not directly lethal to fish, the cumulative effects of elevated water temperatures and flows stress fish.

6.3 WILDLIFE

The development of irrigated agriculture, including the Yakima Project, has affected wildlife in several ways. This section focuses on the impacts to wildlife due to project development and not project operations. Effects described in this section include: 1) effects of conversion of habitat to agricultural and other purposes; 2) effects of alteration of the hydrologic cycle in the basin; 3) effects of project structures; and 4) indirect effects. Development of agricultural land and construction and operation of associated facilities, combined with other changes in the basin, have altered numbers, diversity, and distribution of native and non-native wildlife species. Physical habitat, mobility, food supply, and interspecies interactions have been affected across a variety of habitat types.

6.3.1 Conversion of Habitat

Conversion of shrub-steppe and riparian habitat to agricultural use has directly eliminated about a half million acres of native habitat. Shrub-steppe associated species such as sage and sharp-tailed grouse, sage sparrow, brewers sparrow, etc., are now significantly low levels. Sage grouse have been proposed for listing as a threatened species under the ESA. Native plants and animals have been directly replaced by domestic plant and animal species dependent on irrigated agriculture.

Conversion has introduced weeds and other non-native plant and animal species which have competed with and replaced natives. Irrigated agricultural land favors different assemblages of species than the native habitats it displaces.

Natural stream side channels and tributaries have been converted to canals and drains, causing loss of these habitats. Timing of flow and morphology in these channels has been highly altered, causing loss of natural function.

Unbroken agricultural development, along with other development, has interrupted connectivity of habitats e.g., riparian to upland. This is particularly evident with big-game species that are unable to reach winter range in lowland and riparian areas, and are thus dependent on feeding programs. Conflicts between wildlife and agricultural uses of land have been addressed by fencing out, trapping, or killing the wildlife.

Reclamation project canals often intersect natural watercourses in a manner which precludes upstream movement of fish and other aquatic organisms (i.e., marginal or impassable water crossing structures). In addition, these crossings sometimes also create a barrier to movement of terrestrial organisms in the riparian areas (consider, for example, the KRD canal crossing of Taneum Creek).

6.3.2 Alteration of Hydrologic Cycle

Interruption of flood cycles by impoundment along with structural exclusion of river from floodplain has reduced riverine wetland habitats, which were the predominant pre-development wetlands in the Yakima Valley. Loss of floodplain inundation has altered habitats by removing ability of native vegetation (e.g., cottonwoods) to reproduce and survive; and reducing nutrient cycling and productivity of aquatic invertebrates; and other plant and animal species that form important components of the food web.

Loss of channel-forming flows, which through created cut-and-fill alluviation, created a complex floodplain mosaic of channels, backwater areas, islands, pools, and riffles. This mosaic provided substantial habitat for fish and wildlife. Approximately 80 percent of Washington's terrestrial species use wetlands, riparian areas, and their buffer areas.

Delivery of irrigation water has created upland wetlands, both in the delivery systems and in tailwater wetlands. Some wildlife has taken to artificial wetlands in lieu of lost natural riverine wetlands.

Construction of agricultural drains has dewatered/eliminated natural floodplain wetlands, as well as wetlands associated with alluvial fans and non-floodplain wetlands. This eliminated wetland habitat and adversely affected (impoverished) adjacent upland habitats by removing diversity of plant communities and habitat structure. (High percentage of native wildlife in Central Washington use wetlands during some life stage.)

Hydrologic alteration has caused loss of native vegetation and replacement by non-native vegetation.

Irrigation related changes in sediment dynamics have affected sediment delivery to wetlands, side channels, and main channels, in turn affecting the amount and type of submersed macrophyte growth. Many species of wildlife are dependent on healthy native stands of submersed macrophytes.

Release and/or delivery of water to stream channels has resulted in adverse changes in channel geometry/pattern, substrate, floodplain, and vegetation. Unnatural high flows scour the bed and flush out spawning gravels. The timing of these summer-long high flows favors development of exotic plants such as reed canary grass, and hinders establishment and growth of native plants such as black cottonwood. This flow pattern also adversely affects native salmonid fishes and aquatic mammals such as beaver.

Flow Regime -

Dam construction and operation drastically altered the natural flow regime of the Yakima River. The current flow regime produces flows which: 1) are unnaturally low during fall and winter; 2) reduce available fall and winter rearing habitat for salmonids; 3) fail to produce "freshet" flows or spring flood flows, which formerly helped flush smolts through the system; 4) have unnatural fluctuations which strand and kill fish or displace them to suboptimal habitat; and 5) have unnaturally high flows all summer which result in channel erosion and loss of habitat structure such as LWD.

6.3.3 Effects of Project Structures

Canals block migration corridors, especially for big-game species which may be unable to cross or may suffer mortality. Dams block fish passage, in turn reducing the value of these blocked areas to wildlife species that are dependent on these fish for foraging.

Impacts of Reservoir Level on Fish Passage Into Reservoir Tributary Streams and Fish Utilization of These Tributaries - Both Within and Above the Elevation of the Reservoir -

Construction of Keechelus, Kachess, Cle Elum, Bumping, and Rimrock Dams inundated the lower reaches of the tributary streams of the natural lakes and Tieton River. The clearing during the original dam construction coupled with Reclamation's operation of the dam (period and timing of inundation) has eliminated the riparian zone of these streams and destabilized the channels. During periods when the channels are exposed above the surface of the lake, they lack the shade and cover normally provided by shoreline vegetation, and the instream habitat provided by LWD.

The lack of shoreline and instream structure leads to channel instability, a lack of pools, and impairment of fish passage during years of low flow. In particular, the ability of bull trout and kokanee to access Gold Creek can be affected. Tributary access may also be a problem for other fish. Tributary access has not been investigated for spring spawning fish which ascend tributary streams during low pool while the reservoir is filling. A lower reservoir level or different operating pattern could allow restoration of stable stream channels that provide functional habitat for fish and ensure upstream passage of fish to spawning and rearing habitat.

Fish Passage Over Dams -

The original dams were constructed without providing for fish passage, resulting in significant impacts to resident and anadromous fish species. Sockeye and coho salmon spawned in the headwaters of the Yakima River and sockeye reared in the natural lakes until the dams were constructed. Subsequently, sockeye have been extirpated from the Yakima basin. Steelhead/rainbow trout access to upper tributary streams was also blocked by the dams. Bull trout and pigmy whitefish populations in the Yakima basin are isolated by Keechelus and other dams in the basin.

The large runs of anadromous fish were the underpinnings of the food chain/energy flow in the Yakima basin. The loss of this annual source of nutrients contributed to the decline of top level carnivores (e.g., bald eagle, grizzly bear) and lowered the productivity of the basin for all wildlife. Recovery of bald eagles and grizzly bears depends upon the restoration of an abundant, easily available food supply such as fish runs.

Wildlife Movements -

North-south wildlife movements are restricted across the Snoqualmie Pass Corridor. The inundation of the original Lake Keechelus shoreline eliminated riparian and forested areas which could serve as north-south connecting corridors. The inundation, combined with highways and urban development, has restricted wildlife movement.

Wildlife Associated With Late Successional Forest -

The area surrounding all of the Reclamation reservoirs was once habitat for late seral-associated wildlife such as spotted owl, pileated woodpecker, pine martin, goshawk, etc. Populations of these species are now all at very low levels because of habitat loss throughout the Yakima basin. The clearing/inundation of terrestrial habitat by Reclamation dam projects permanently removed habitat and contributed to these population declines.

Habitats Lost -

Creation of the reservoirs inundated areas of several habitat types (old growth forests, wetland, riparian, instream, etc.) that are now severely limited and are listed as Priority Habitats within WDFW's Priority Habitats and Species Program. Priority wildlife species that were probably impacted by the loss of these habitats include: cascade frog, Larch Mountain salamander, bald eagle, common loon, spotted owl, Harlequin duck, great blue heron, fisher, pine marten, and Townsend's big eared bat.

Large Woody Debris -

Dam construction blocked recruitment of LWD from the upper basins to the Yakima River, Naches and Tieton Rivers, and reduced habitat diversity downstream in the Yakima River. Currently, LWD is captured by the dam and subsequently piled and burned.

6.3.4 Indirect Effects

The native wildlife populations in the Yakima basin were extremely dependent on the constant energy sources brought up from the oceans by the fish runs. The loss of the runs caused a large loss in energy to the system, altering wildlife population dynamics by causing less vegetation, less invertebrates, and less wildlife dependent on eating salmon (bears, eagles, 137 species; see report on Salmon and Wildlife).

6.4 RIPARIAN VEGETATION

Introduction

Riparian areas are lands directly adjacent to creeks, rivers, streams, ponds, or lakes where surface water influences the surrounding vegetation. The riparian zone is the transition between uplands, where there is seldom standing water, and the waterbody where free-flowing or standing water is common. Riparian ecosystems are wetland ecosystems, which have a high water table (where saturated soils [hydric soils] are relatively close to the ground surface) because of proximity to an aquatic ecosystem or subsurface water. At a minimum, the width of the natural vegetation zone extends one active channel width on each side of a free-flowing waterbody, from the edge of the active channel out onto the floodplain.

Riparian vegetation filters sediments and can absorb nutrients, chemicals, and other pollutants that might otherwise be released into surface waters or aquifers. Riparian vegetation also decreases erosion and stabilizes streambanks by binding soils. Shade caused by overhanging riparian vegetation or by a riparian canopy cools a stream by reducing heating by solar radiation. Vegetation further reduces erosion by providing roughness at the interface between the streambank and the water. Water velocity, and thus the energy available for transport of sediment, is decreased. Streambank building may occur during high flow periods as sediments are deposited. Deposits of fine fertile soils on floodplains are due to the filtering effect of riparian vegetation and the slowing of flow velocity. Additionally, riparian vegetation provides critical habitat in the aquatic food web, as well as habitat and forage for many wildlife species.

Reservoirs -

There is essentially no true riparian vegetation surrounding the reservoirs that supply water to the Yakima Project. Most natural riparian vegetation was removed prior to construction of the reservoirs, and no new riparian vegetation has developed due to extreme fluctuations of the water levels in the reservoirs. The primary function of these reservoirs is to collect and release water for irrigation supplies during the year. Current operations can cause the water level within the reservoir to fluctuate dramatically, as much as 100 feet or more in some cases (e.g., Lake Cle Elum). As the water table rises and falls, different portions of the potential riparian area are either inundated or dewatered, often for months at a time, preventing the growth of riparian vegetation.

Main Stem of the Yakima River -

Flow fluctuations within the Yakima River that occur as part of Yakima Project operations may exacerbate erosion of riverbanks, harming native riparian vegetation. Pollution from agricultural return waters may impair the riparian vegetation along the river. Impaired riparian vegetation is especially evident in the lower Yakima basin. Pesticides, sediment, and unnatural nutrient balances may deter native plant growth, possibly promoting the growth of non-native species. In the late summer in the lower basin, very low water levels in the Yakima River may cause the water table to drop below the potential root zones of native riparian vegetation, preventing the growth of these plants.

A by-product of the Yakima Project that has become a key element in Yakima basin water management is flood control. Flood control reduces both flood frequency and the extent of flooding, allowing counties to permit the development of the floodplain for other uses (agricultural, home building, etc.), that often results in diminishing riparian vegetation. Grazing livestock can damage riparian vegetation, as can the development of home sites along the river or tributaries, as new residents clear areas adjacent to the waterbody. However, not all development is necessarily detrimental to local riparian vegetation. For instance, upslope irrigation may actually raise a surface water table and increase the water available to some natural riparian areas, thereby increasing the growth of riparian vegetation.

Tributaries of the Yakima River -

Development of irrigated agricultural areas made possible by Reclamation projects such as the Yakima Project have reduced riparian areas by encouraging development of farmland in riparian and adjacent arid zones.

Additionally, some natural stream channels are used to deliver irrigation water. In the upper Yakima basin many of the natural streambeds are used as delivery canals. Water is put into these waterbodies upstream to provide water to downstream irrigators. The flow fluctuations that occur as a result of these practices may erode streambanks and destroy natural riparian vegetation.

Canals and Delivery Ditches -

Very little riparian vegetation exists along canals and ditches. Because canals and delivery ditches are man-made, they originally had no native riparian vegetation. Generally, vegetation along these conveyances is removed by irrigation district personnel or by irrigators to simplify maintenance. Delivery canals must be kept free of large plant growth for proper operation. Both mechanical and chemical measures are used to remove vegetation.

Drains -

Drains in the Yakima basin generally have little, if any, riparian vegetation. Some of the drains were developed in natural watercourses. Their function has been to remove irrigation tailwater from cultivated areas and to lower the water table in areas of shallow groundwater. Because drains often rapidly fill with sediment carried by agricultural return water, they must be frequently cleaned with heavy equipment. Riparian vegetation is destroyed during maintenance activities. Additionally, the numerous pesticides and inappropriate nutrient levels carried in the agricultural return water can be harmful to native riparian plants. It should be noted that some water will reach riparian areas through and because of irrigation return flows. Some of these return flows can create wetlands in areas where none existed before.

6.5 FLOODPLAIN FUNCTIONS/CHANNEL MORPHOLOGY

Introduction: Importance of Floodplain Function to River Ecology

Reaches associated with alluvial floodplains have been shown to be centers of biological productivity and ecological diversity in gravel bed rivers (Stanford and Ward, 1988; Independent Scientific Group, 1996). Properly functioning floodplain reaches extend the functional width of the river well beyond the main channel and provide key benefits to cold water fish. Floodplain reaches contribute to baseflows; thermal moderation; nutrient cycling and food web production; off-channel habitats; and are vital to sustain healthy fish populations in gravel bed river systems such as the Yakima. Proper floodplain function requires an appropriate flow regime (normative hydrograph) interacting with accessible floodplains. In the Yakima River basin, a mix of project and non-project alterations of both the hydrograph and physical floodplain structure impairs floodplain functions.

Properly functioning floodplains capture flood flows, decreasing downstream flood damage to instream and out-of-stream resources. As overbank flow spreads and slows down on the floodplain, a portion of the water infiltrates into permeable floodplain alluvium, reducing peak flows and storing in the shallow aquifer oxygenated, thermally moderate water that later contributes to baseflow. The alluvial aquifer system associated with floodplain reaches has been said to function "as the flywheel on an engine," sustaining streamflow through times of little precipitation and runoff (Kinnison and Sceva, 1963).

Temperature is a key environmental variable for salmonids and associated organisms. By storing flood waters in subsurface alluvium, insulated from the thermal influences of atmospheric and solar heating, floodplains moderate river temperature, both through bulk cooling and by creating localized thermal refugia at groundwater discharge areas. In addition to providing protection against summer heating, groundwater provides warmer water at discharge areas and prevents icing in winter.

Properly functioning alluvial floodplains provide abundant, complex, diverse habitats for cold water fishes. Flood flows form and maintain the channel network including side channels. Spring brooks receiving discharging groundwater provide low velocity, thermally moderate, food rich habitat for juvenile fish.

Floodplain alluvial aquifers generate food web support in the hyporheic zone. Interspatial spaces in gravel are habitat for invertebrates. Dissolved and particulate organic matter are broken down by bacteria which form algal mats on cobble surfaces. Larval stages of aquatic invertebrates spend most of their life histories consuming the mats, putting on mass before a brief flighted stage during which they breed and die.

Pre-development Conditions -

Pre-development and current conditions are summarized in Ring and Watson (1999). In the Yakima basin, bedrock constrictions between alluvial subbasins control the exchange of water between streams and the aquifer system. Under pre-development conditions, vast alluvial floodplains were connected to complex webs of braids and tributary channels. These large hydrological buffers spread and reduce peak flows, promoting infiltration of cold water into the underlying gravels. Side channels and sloughs provided a large area of edge habitat and a variety of thermal and velocity regimes. For salmon and steelhead, these side channel complexes increased productivity, carrying capacity, and life history diversity by providing suitable habitat for all freshwater life stages in close physical proximity. The hyporheic zone (zone of shallow groundwater made up of downwelling surface water) extended the functional width of the alluvial floodplain and hosted a microbe- and invertebrate-based food web that augmented the food base of the ecosystem. As snowmelt-generated runoff receded through the summer, cool groundwater discharge made up an increasing proportion of streamflow. Much of this groundwater upwelled from the gravel into complex channel networks upstream of bedrock constrictions.

River/floodplain interactions provided cool, clear base flows, possibly including times of low flow and high air temperatures, creating thermal refugia for out-migrating smolts and returning adults moving through the hot lower basin. In winter, upwelling groundwater prevented freezing and drove the flow of oxygenated water through the gravel substrate, providing excellent conditions for incubating eggs and alevin.

Current Conditions -

Floodplain isolation and channel simplification, combined with inversion and truncation of the natural hydrograph, have dramatically reduced river floodplain interactions and degraded the aquatic environment. The floodplain is isolated from the river by diking, channelization, wetland draining, gravel mining, and highway and railroad building. Many of these same activities have eliminated or isolated vast areas of side channels and sloughs. River operations for irrigation and flood control alter the natural hydrograph by impounding spring freshets, substantially increasing summer flow, and decreasing winter flow. A common effect of these developments is a sharp reduction in the frequency with which spring floods recharge the alluvial floodplain aquifer system. Water temperatures in the lower river are therefore higher in the summer, and the number and extent of thermal refugia are reduced.

Effects of Project Operations -

Truncation of flood peaks by capture in reservoirs reduces the frequency, duration, magnitude, and spatial extent of floodplain inundation. This decreases the size of the regulatory floodplain, thus project operations have indirectly allowed commercial and residential development of floodplains.

By reducing recharge from overbank flow and increasing irrigation induced recharge, which has different timing and location, project operations have altered the quantity, quality, and timing of groundwater discharge to the river and floodplain spring brook habitats.

6.6 IRRIGATION

Although the original purpose of the Yakima Project was irrigation, the Yakima Project is currently operated as a multi-purpose project. The priority for the various purposes depends on contracts, court decisions, policy, time of year, and the status of the water supply. Project purposes fall into five categories: fish and wildlife, irrigation, flood control, power generation, and recreation. Since the various project purposes have competing demands, it is inevitable that compromises must be made in one or more areas to maximize benefits for all purposes. This section will attempt to highlight compromises made in the area of irrigation to benefit other uses. Compromises made in other purposes to benefit irrigation are highlighted in other sections.

6.6.1 Recreation

Most project facilities are not operated to directly benefit recreation. Project recreation benefits are generally incidental to other project purposes. The one exception is that the project is operated to benefit recreation at Clear Lake. To maximize benefits for recreation, Clear Lake Reservoir must be full. The Forest Service must be notified by August 10th of Reclamation's intent to drawdown the reservoir to meet irrigation demands. If the reservoir is used for irrigation, Clear Lake storage must be released between about October 5th and October 20th to avoid impacts to spawning kokanee. This constraint can create difficulty in fully utilizing Clear Lake storage for irrigation purposes.

6.6.2 Flood Control

To maximize use of a reservoir for flood control, it must be empty prior to a flood event, but to maximize its use for irrigation it must be full at the beginning of the peak delivery period. These two goals are often in direct conflict. In 1995, flood control operations caused Keechelus Reservoir to be short by 10,000 acre-feet.

6.6.3 Power

Power generated in the Yakima valley is used to pump water to lands above the Roza Canal and to provide power for use outside the Yakima valley. Power generation has no detrimental effect on irrigation.

6.6.4 Fish & Wildlife

The flip-flop operation creates stress on the storage system by causing extreme imbalances in reservoir storage near the end of the irrigation season. The flip-flop operation also causes some reservoir outlet gates to be operated at near full capacity for extended periods of time. Cle Elum Reservoir is near empty and Rimrock Reservoir is near full in early September. This has the effect of "putting all your eggs in one basket." To provide maximum flexibility in operations, multiple reservoirs are preferably drawn down at a near equal rate. Then, if a gate failure limits access to one reservoir, other reservoirs can be drawn upon to meet demand. In 1979, gate repairs at Cle Elum Reservoir limited access to Cle Elum storage creating a water-short year for irrigation.

In some cases, higher target flows reduce the amount of TWSA for irrigation. Increases in winter incubation flows at times reduce the ability to refill the reservoirs in the winter. Increases in target flows at Parker reduce TWSA for other uses. In water-short years any decrease to TWSA is felt directly by proratable irrigation districts in the form of harsher rationing. If 1977 flow targets were used during the 1994 irrigation season, the rationing level for proratable irrigation districts would have been about 45 percent rather than 37 percent due to the increase of Title XII target flows.

6.6.5 Irrigation

Since the project started, the irrigated acres increased from 121,000 acres in 1902, to approximately 465,000 acres today. A quote from C.R. Lentz 1974, helps illustrate the effect of the project on irrigation. "By 1902, there were an estimated 121,000 acres under irrigation in the Yakima Basin, representing about 25 percent of the present irrigable development. This acreage was served by natural flows in the river and tributaries, with none of the present large storage dams and reservoirs in existence. The natural runoff was inadequate to insure a dependable water supply for the development even at the turn of the century." Even with the reservoirs in place, some level of rationing is still required in about 1 out of every 4 years. In the Yakima valley $500,000 million to $1 billion worth of irrigated crops are raised annually.

6.7 HYDROELECTRIC POWER

Competing water uses limit the extent to which water may be managed for power production. There are presently nine hydroelectric power plants within the Yakima basin. Of the nine power plants, only four are operating with non-consumptive use, power water diversion rights, generating marketable power production. The Chandler and Roza hydroelectric plants are operated by Reclamation, and PacifiCorp (parent company, Scottish Power) operates the Naches, and Naches Drop hydroelectric plants (Wapatox). The YTID's two hydroelectric plants, Cowiche and Orchard Avenue, are in-line plants operating only during the irrigation season, selling the generated power to PacifiCorp. The other three hydroelectric plants include two units that are in use by WIP and one unit operated by a private party (J. Leishman), all of which make electrical power for within-system pump use or domestic service. These last five power plants make co-use of the irrigation water diversions within the irrigation districts' systems for power production. All of the power plants are served by water supplied from diversion dams via canal systems.

All main stem hydroelectric power plants operate as run-of-the-river plants. That is, they operate with available flows from the Yakima and Naches Rivers. Power generation at the Chandler and Roza plants is subordinated to provide minimum fishery flows in the respective bypass reaches. In general, power water at Roza and Chandler Power Plants is limited to any surplus amounts in excess of irrigation requirements, and in the non-irrigation season to available flows. The Wapatox hydroelectric plant has no available storage water rights. If Naches River natural flows are insufficient to maintain a 300 cfs power water diversion for the Wapatox plant, no inflow can be stored in either Rimrock or Bumping Reservoirs. Inflow may be bypassed at the 2 reservoirs to attempt to maintain the 300 cfs natural flow minimum to satisfy the downstream Wapatox power water right. The Wapatox hydroelectric plant, having a water right priority date of 1904, has a natural flow right which is junior to most other upstream natural flow users. The Wapatox water right is senior to many Yakima Project water rights, many of which have a priority date of 1905.

6.7.1 Federal Columbia Rivers Power System - Power Production & Irrigation Assistance

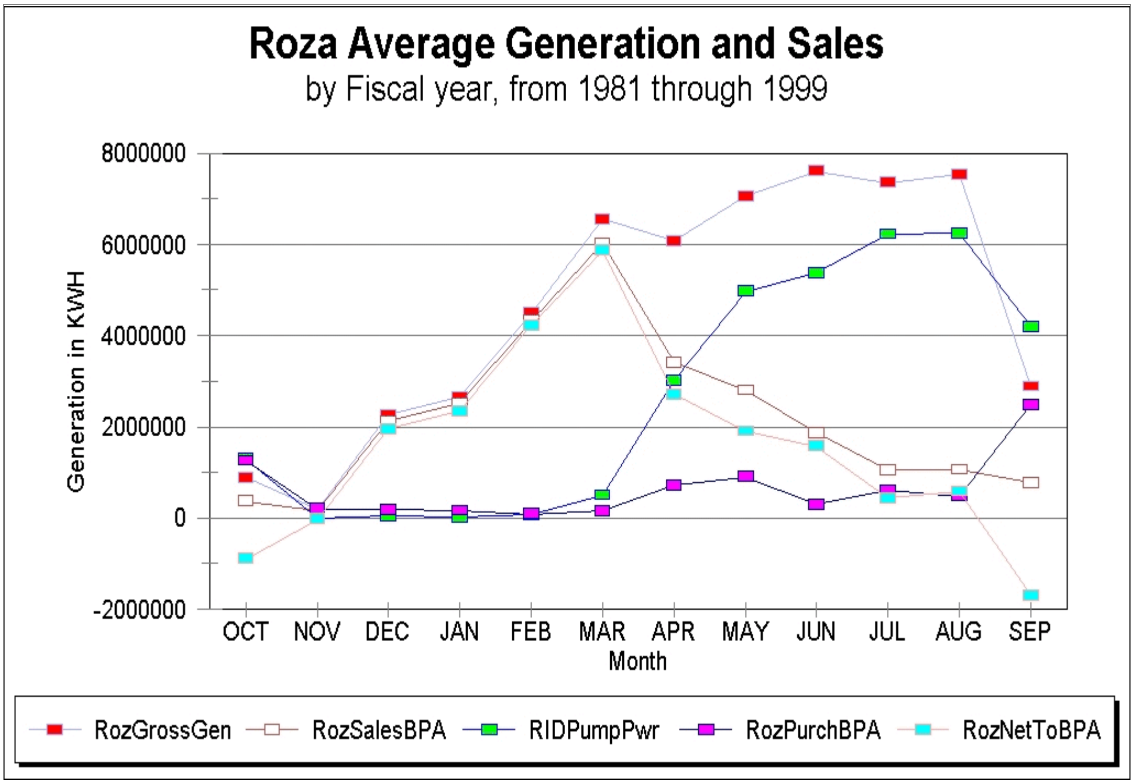
The Reclamation's Yakima Project has 2 of the 30 operational, federally owned and operated, hydroelectric facilities within the Columbia River Basin. The power generated by these Federal facilities is marketed by the Bonneville Power Administration (BPA), a Federal agency under the Department of Energy. The financial organization under which the power is marketed is known as the Federal Columbia River Power System (FCRPS). In addition to marketing the power from these Federal facilities, BPA also operates and maintains about 80 percent of the region's high-voltage transmission lines.

BPA is a self-funding agency that covers its costs by selling the power generated at the Federal dams wholesale to the region's public utilities, municipalities, investor-owned utilities, and some large industries. The revenues received from power sales are used to fund BPA's operations and maintenance. These revenues are also used to repay annually the Federal Treasury for the "power share" of the capital investments in hydroelectric facilities of the Columbia River Basin funded through appropriations that are owned and operated by Reclamation and the U.S. Army Corps of Engineers (Corps). The power share of the Federal capital investment in each dam was determined at the time the dam or facility was authorized. The other purposes for which a dam may be authorized by Congress are, for example, flood control or navigation. BPA also repays the Treasury for the power share of the annual operations and maintenance expenses of these agencies.

6.7.1.1 Power Production

Roza Power Plant -

The Yakima Project generates power at the Roza Power Plant and at the Chandler Power Plant. The primary purpose for the power generation at Roza is to supply power to pumps for the delivery of irrigation water to RID members. At any time the power generated by the Reclamations's Roza facility that is excess to Roza load demands and project usage (including station service), the excess power is marketed through BPA under the FCRPS. This is accomplished through an operating agreement between Reclamation and BPA. During the irrigation season, when the irrigation district's demand for power exceeds the power supply available from the Roza Power Plant, the district receives additional power from BPA. This annual exchange of power between the Yakima Project and BPA is defined in a shaping agreement between the two agencies. The amount of energy BPA is required to supply under this agreement is capped at 40,000,000 kWh per year. The Roza Power Plant has generated a gross annual average of 55,535,289 kWh during the past 19 years. A graph illustrating the annual average generation of power at the Roza Power Plant is shown below.

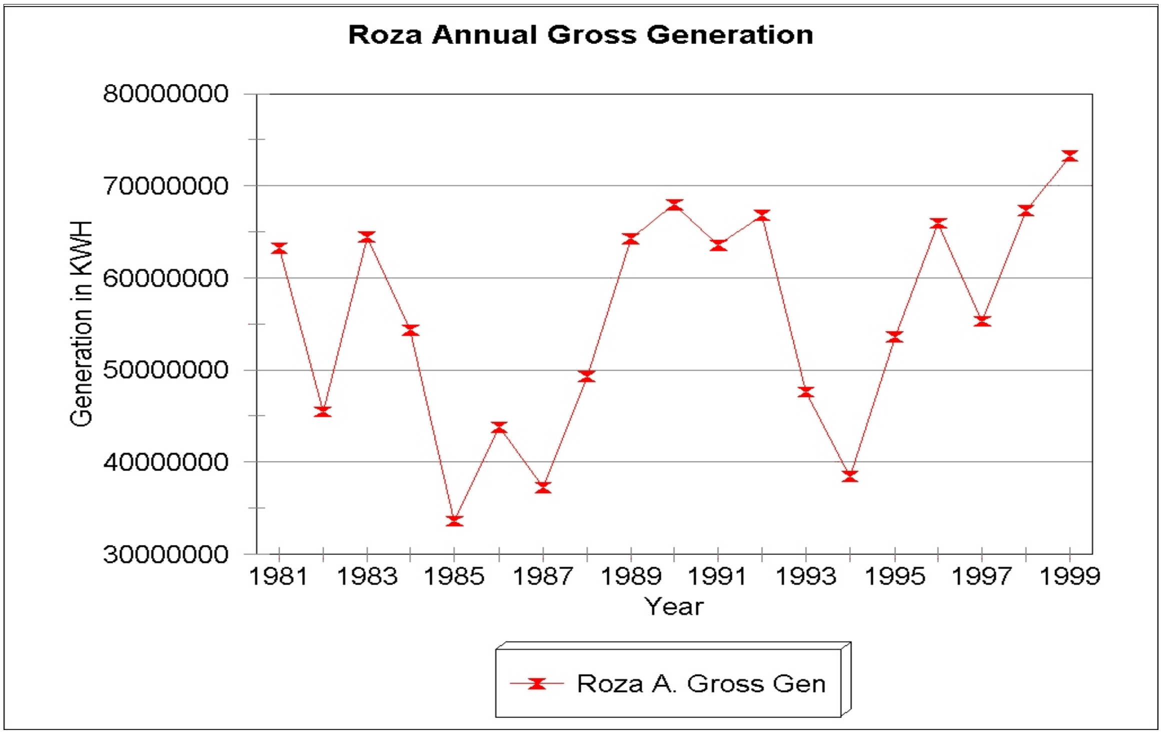


The Roza graph displays the average annual generation at the Roza Power Plant for the period 1981 through 1999. The categories identified in the analysis are Roza gross generation (RozGrossGen), Roza power delivery to BPA (the power deliveries are tracked as credits - no funds are exchanged) (RozSalesBPA), Roza demand for make-up pump power (RozPurchBPA), RID pump requirements (RIDPumpPwr), and Roza net power for BPA marketing (RozaNetToBPA). The graph shows that over the past 19 years, BPA has marketed a net annual average of 18,974,147 kWh from the Roza Power Plant.

Power Subordination -

Roza Power Plant

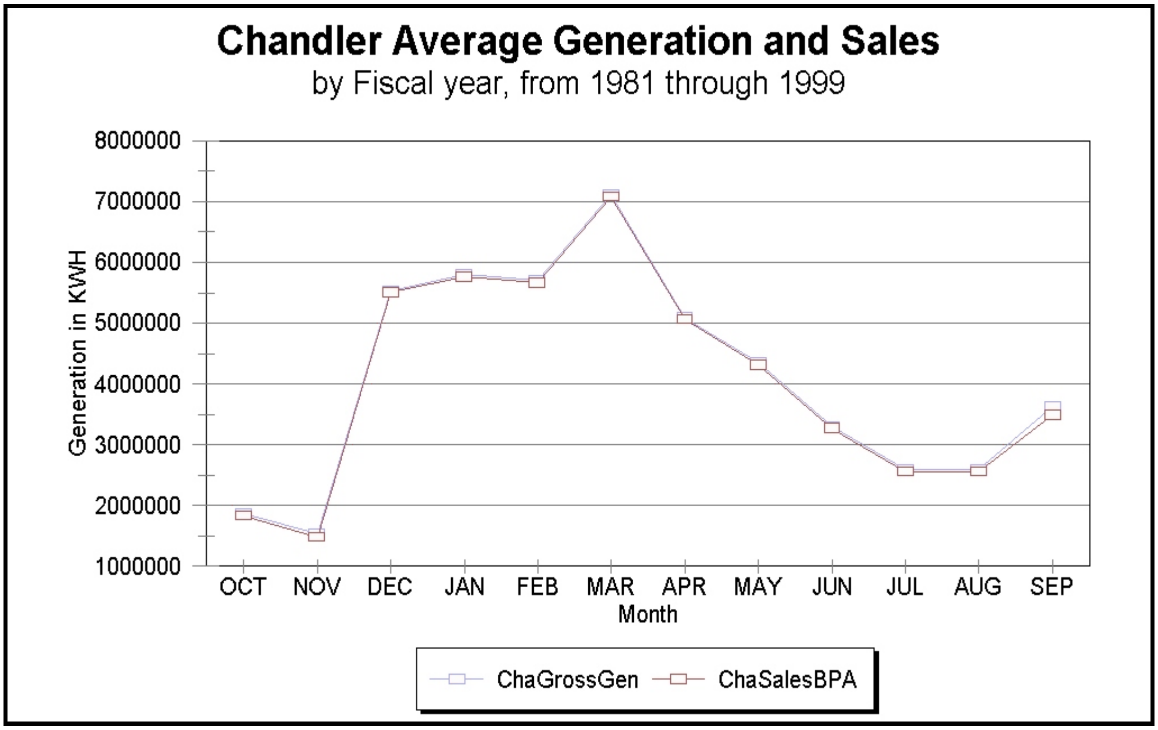
Power subordination occurs when power generation is reduced or shutdown, allowing the power water diversion flows to remain in the river system to protect the fishery resources or to enhance fish passage. Currently, power water for electric generation at Roza Power Plant is subordinated slightly to improve fishery flows in the Yakima River below Roza Diversion Dam (RBDW). Reclamation does not have specific direction on the authority to subordinate Roza Power Plant, but maintains an informal agreement in consultation with SOAC, BPA, and others to subordinate power generation to maintain a 400 cfs minimum in the river. A graph illustrating the gross yearly generation of power at the Roza Power Plant is shown below for the period 1981 through 1999. The total loss of power production due to subordination is difficult to quantify, as no daily records are currently kept of the actual amount of daily subordinated power. Therefore, the gross yearly generation totals do not portray an accurate picture of the effects of power subordination as the daily amounts of subordination are washed out in the yearly totals. Power is being subordinated as a rule at the rate of, for every 100 cfs per hour left in the river or reduction of canal flows, costs 1 MW (1,000 kWh) of power generation. The needed rate of power subordination can change hourly and should be tracked accordingly.



6.7.1.2 Power Production

Chandler Power Plant -

The Yakima Project generates power at the Chandler Power Plant with the use of two hydroelectric generation units. All of the power generated by these units, except for station service, is marketed by BPA. The Chandler Power Plant has generated a gross annual average of 49,052,684 kWh during the past 19 years. A graph illustrating the annual average generation of power at the Chandler Power Plant is shown below.

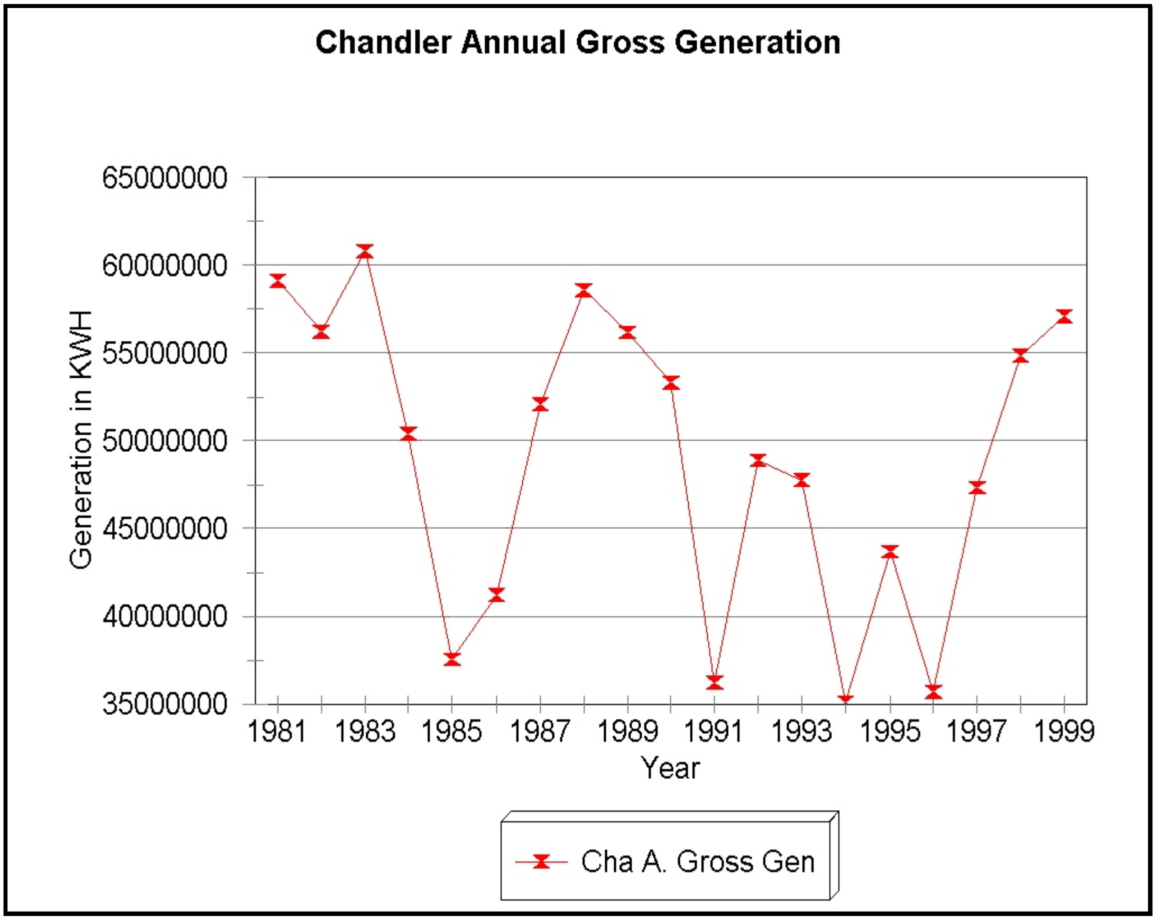


The Chandler graph displays the average annual generation at the Chandler Power Plant for the period 1981 through 1999. The categories identified in the analysis are Chandler gross generation (ChaGrossGen) and Chandler marketable power delivery (sales) to BPA (ChaSalesBPA). The graph shows that over the past 19 years, BPA has marketed a net annual average of 48,544,837 kWh from the Chandler Power Plant.

Power Subordination -

Chandler Power Plant

Power subordination occurs when power generation is reduced or shutdown, allowing the power water diversion flows to remain in the river system to protect the fishery resources or to enhance fish passage. Reclamation has the authority to subordinate Chandler Power Plant as identified in YRBWEP. Power production is subordinated to various flows throughout the year. In April through June, power is subordinated to 1,000 cfs over Prosser Dam as measured at Yakima River at Prosser (YRPW). During the remainder of the irrigation season, the subordination target is 450 cfs or the YRBWEP Title XII target flow, whichever is higher. The agreed subordination target was for 450 cfs through the non-irrigation season. A graph illustrating the gross yearly generation of power at the Chandler Power Plant is shown below for the period 1981 through 1999. The total loss of power production due to subordination is difficult to quantify, as no daily records are currently kept of the actual amount of daily subordinated power. Therefore, the gross yearly generation totals do not portray an accurate picture of the effects of power subordination as the daily amounts of subordination are washed out in the yearly totals. Power is being subordinated as a rule at the rate of, for every 100 cfs left in the river or reduction of canal flows, costs 1 MW (1,000 kWh) of power generation. The needed rate of power subordination can change hourly and should be tracked accordingly.



6.7.1.3 Irrigation Assistance

Under Reclamation law, irrigation districts that benefit from the construction of federally funded irrigation systems are usually under an obligation to repay the U.S. Treasury for a portion of the original construction cost for their facilities. As part of the Yakima River Basin Project, approximately $140 million in Federal funds were invested to construct the irrigation systems. Based on several Acts of Congress (1902 Reclamation Act; 1939 Reclamation Act; Third Power Plant, Grand Coulee Dam), Reclamation law has evolved over time, modifying the repayment responsibilities for irrigation districts. One of the changes that occurred over time was the extension of the repayment period from 10 years up to 66 years.

Current Reclamation law authorizes Reclamation, based on a standard “farm budget” analysis of an irrigation district’s ability to repay, to assign a portion of a district’s U.S. Treasury repayment liability to the FCRPS. This repayment is called “irrigation assistance.” Under the authority of the Third Power Plant, Grand Coulee Dam Act, the FCRPS is authorized to repay the irrigation assistance from "net revenues" of power sales of the FCRPS. ("Net revenues" are defined as those revenues over and above the amount needed to recover all FCRPS' costs allocated to power, including the cost of acquiring power by purchase or exchange, and previously authorized irrigation assistance.) Total irrigation assistance due the U.S. Treasury as of September 30, 1997, was $10.6 million. The final payment is due in 2026.

6.7.2 Private Power Production

Private power production is represented in the Yakima basin by several small hydroelectric power plants with marketable power production that is marketed by a private utility company, such as PacifiCorp. Yakima-Tieton Irrigation, PacifiCorp, and possibly the Leishman facility, all develop private (non-BPA) marketable power.

6.7.2.1 Private Power Production

Wapatox Power Plants -

The Wapatox Drop Power Plant and Naches Plant were constructed by Northwest Light and Water Company, and are now operated by PacifiCorp, via Pacific Power & Light Company, the successor to Northwest Light and Water Company. The plants are located on the Wapatox Power Canal (diversion point is located on the Naches River at RM 17.1 with 500+ cfs canal capacity), downstream and east of the town of Naches. The plant capacity of the single Drop Power Plant unit is approximately 1,100 kW. The Naches Plant capacity is approximately 5,200 kW, being 2,200 kW from one unit, and 3,000 kW from the second unit. The total generation capacity of the 2 plants is 6,300 kW. The canal and power plant are operated year-round, except for 2 to 4 weeks of maintenance shutdown, with generation becoming a part of and marketed by PacifiCorp's commercial power service. Based on available data, PacifiCorp's average annual generation exceeds 36,264,000 kWh of marketable power.

Power Subordination -

Wapatox Power Plants

Power subordination occurs when power generation is reduced or shutdown, allowing the power water diversion flows to remain in the river system to protect the fishery resources or to enhance fish passage. This power plant diversion has a year-round natural flow right of 300 to 450 cfs, and diversion from the river (at Naches RM 17.1) is allowed within this range so long as the flow is naturally available and the rights of senior diverters and users are satisfied, including flows to protect anadromous fish life. Reclamation is not obligated to provide storage flows at any time. During non-irrigation season (winter), the power diversion water is informally subordinated to maintain a 125 cfs instream flow in the Naches River below the Tieton River below the mouth of the Tieton River. The total loss of power production due to subordination is difficult to quantify as no daily records are currently kept of the actual amount of daily subordinated power.

6.7.2.2 Private Power Production

Yakima-Tieton Irrigation District Power Plants -

The YTID operates the Cowiche and Orchard Avenue hydroelectric plants as pressure-reducing stations for the pressurized pipeline distribution system completed in 1986. The generators at the 2 plants have a combined capacity of 3,000 kW, operating only during the irrigation season, April through October. The operation of the plants is contingent upon the water demand with the district during the irrigation season. From WY 1987 to WY 2000, the yearly gross generation ranged from a low of 6,665,572 kWh to a high of 8,154,605 kWh, with an average of 7,533,143 kWh of marketable power that was sold to and marketed by PacifiCorp's commercial power service.

6.7.2.3 Private Power Production

Leishman Power Plant -

The Leishman Power Plant serves as energy dissipators on an irrigation pipeline system, making use of 2 generating units with rated capacities of 25 kW and 7.5 kW to reduce line pressure, and supply electrical power for a farming and ranching operation. The power plant utilizes an existing irrigation tailwater collection system to supply water for the generation units during irrigation season. This non-consumptive use of water is permitted for use from April 1st to October 1st. Note: the power generation excess to farming and ranching operation may be sold to Puget Power & Light Company. Currently, the volume of marketable power is unconfirmed.

6.8 FLOOD DAMAGE REDUCTION

Project operation of the reservoir system yields over $5 million worth of flood control benefits as assigned by the Corps. According to the Columbia River Management Group Annual Report for 1999, the value of accumulated flood control benefits for the period 1950-1998 is $252,550,000 and the estimate for 1999 alone was $5,756,000. The benefit in 1996, the last big flood year, was $32 million.

Because the system is drawn down in the autumn of the year, there is flood control space available in late fall and early winter every year. Most flood benefits are from winter flood control because spring floods are historically lesser events in this basin. Springtime flood benefits accrue as the reservoirs are filled on a schedule to track the runoff, with the goal of having a full system in late May or early June. The flood space schedule is defined by a family of flood rule curves tracking runoff forecast and reservoir space.

The system is not fully controlled. Project reservoirs can only affect the timing of the peak event, and depending on the event and space available, can decrease the magnitude. For instance, in February of 1996, project regulation diminished a natural peak of 92,700 cfs at the Yakima River at Parker to an observed peak of 58,150 cfs.

7.0 RESOURCE OBJECTIVES

This section identifies the resource objectives of the multi-agency members of the Interim Operating Plan (IOP) committee. Some, but not necessarily all of these objectives, are not within the authorities of the Yakima Field Office.

7.1 WATER

7.1.1 Quality

Resource Goal -

To obtain water quality in the Yakima River and its tributaries that fully supports designated uses and meets narrative and numerical criteria of Washington State water quality standards.

Explanation: Water quality standards are composed of two parts: designated uses (fishable, swimmable) and criteria, either narrative or numeric, to protect the uses. (An anti-degradation provision also prevents backsliding.) Both parts of the standards are important and separately enforceable. Of the two, the attainment and maintenance of designated uses is probably the least understood. An example of designated uses for class AA and A waters in the State of Washington, which are the classifications that apply to almost all of the Yakima River and its tributaries, is salmonid spawning, rearing, migration, and harvest. This use is also sometimes described as the use of cold water biota. The Environmental Protection Act (EPA) describes "full support" for cold water biota, including salmon life cycles, as that which supports "thriving, sustainable populations of species which would normally occur in cold water absent water column/habitat degradation. Full confirmation would include attainment of applicable numeric criteria and the presence of a biological community representative of what one might expect for that given ecosystem."

Our understanding of standards is evolving and numeric criteria, while important, does not fully describe the ecological conditions necessary to support the uses of water and the "fishable, swimmable" standard. The resource goal is, therefore, most appropriately expressed both in terms of the water quality that fully supports the designated uses of water quality standards as well as meeting numeric and other narrative standards.

Interim Measures of Success -

Total Maximum Daily Loads

When it is demonstrated that these standards are not being met in any waterbody defined as a "water of the state," the Department of Ecology (WDOE) includes that waterbody on the "303(d) list of impaired waterbodies." The Clean Water Act (CWA) requires the State to prepare and submit this list to the EPA every 4 years, the most recent year being 1998. In the Yakima basin, 57 waterbodies with 22 pollutant parameters were included on the 1998 303(d) list. It is expected that several more listings on the 2002 list will result from recent monitoring. Pollutant listings in the Yakima basin include high turbidity, low dissolved oxygen, high temperature, PCBs, pesticides, metals, pH, ammonia, and fecal coliform bacteria. Several reaches within the basin are also listed for low instream flow. As required by the Federal CWA, 303(d) listed waterbody segments must be addressed for all identified pollutant parameters through the development of a Total Maximum Daily Load (TMDL), or "water clean-up plan," by WDOE. TMDLs are submitted to EPA for approval. A component of the TMDL process is performing a technical evaluation that determines pollutant loading during critical periods; identifies known and potential pollutant sources; defines the maximum pollutant carrying capacity possible for the waterbody without exceeding standards; and allocates that carrying capacity to the sources. Sources of the pollutant may include point, non-point, and natural sources. Seasonal variation and a margin of safety are included in the allocation. The "clean-up plan" describes activities, participants, and schedules necessary to meet water quality standards. The TMDL will often use a phased implementation process, setting defined and measurable interim targets while working toward State standards. A monitoring plan set up to determine effectiveness and success of the implementation activities is an essential component of the TMDL process.

In 1997, a lawsuit was filed against EPA and WDOE for failure to develop TMDLs on 303(d) listed waterbodies in compliance with the Federal CWA. As a settlement to the suit, WDOE signed a three party Memorandum of Agreement (MOA) with the plaintiffs and EPA and agreed, among other requirements, to develop TMDLs for all waterbodies on the 1996 303(d) list by the year 2014. Fulfilling the requirements of this MOA and addressing all listed waterbodies within the State is a priority project for the WDOE.

Several TMDLs are under development in the basin and it is expected that several of the other 303(d) listings may be eliminated with after verification monitoring. WDOE will prioritize the remaining 303(d) listings and develop a time line to address all impaired waters within the next several years. Specific interim measures of success will include the continuing decline of 303(d) listings within the basin and the increase of TMDL implementation activities; the development of TMDLs for all 1996 303(d) listed waterbodies in the basin and/or the removal of those waterbodies from the 303(d) list by June 30, 2013; the attainment of human health criteria for t-DDT (total DDT) in fish tissue and the removal of fish consumption advisories; and the reduction of known pollutant loads in the water column and the attainment of State standards. Activities and water quality indicators will be monitored and tracked by WDOE and other entities within the basin.

Index of Biological Integrity

The Index of Biological Integrity (IBI) offers resource managers an ecologically based method for assessing the health of aquatic ecosystems. The original IBI developed for midwestern streams (Karr 1981; Karr et al., 1986) consisted of 12 fish community parameters, or metrics, divided into categories of species richness, trophic structure, and fish abundance and condition. The 12 metrics were selected to evaluate different aspects of the health of stream ecosystems, and were, therefore, used to reflect changes in community structure or function that might not be assessed by measures of water chemistry or contaminant levels alone. The IBI provides a tool for quantifying changes in ecosystem health as a result of habitat degradation or flow alteration, in addition to chronically poor chemical water quality (Karr and Dudley, 1981).

IOP members believe that the IBI is one tool that can be used as an indicator of progress toward the long-term resource goal for water quality.

The National Water Quality Assessment

The National Water Quality Assessment (NAWQA) is a program of the United States Geological Survey (USGS) designed to describe the status and trends in the quality of the Nation's ground and surface water resources, and to provide a sound understanding of the natural and human factors that affect the quality of these resources. As part of the program, investigations are being conducted in 59 areas called "study units" throughout the nation. These investigations will provide a framework for national and regional water quality assessment. Regional and national synthesis of information from study units will consist of comparative studies of specific water quality issues using nationally consistent information. The Yakima River basin is one of the NAWQA study units, and water quality information developed in that program has been and will continue to be extremely useful in assessing progress toward this long resource objective.

7.1.2 Quantity

Resource Goal -

To develop streamflows in the Yakima River that mimic the unregulated hydrograph in frequency, duration, timing, magnitude; and rate of change to the extent necessary to restore riverine ecosystem processes that support healthy, sustainable native aquatic plant and animal communities; and which also provide for the efficient implementation of other legitimate project purposes.

Explanation: Streamflow quantity and timing are critical components of water supply, water quality, and the ecological integrity of river systems. Indeed, streamflow which is strongly correlated with many critical physicochemical characteristics of rivers, such as water temperature, channel geomorphology, and habitat diversity, can be considered a “master variable” that limits the distribution and abundance of riverine species and regulates the ecological integrity of flowing water systems. (Poff et al., 1997; Power et al., 1995; Resh et al., 1988.)

Interim Measures of Success -

The Range of Variability Approach

The Range of Variability Approach (RVA) derives from aquatic ecology theory concerning the critical role of hydrological variability, and associated characteristics of timing, frequency, duration, and rates of change in sustaining aquatic ecosystems. The method is intended for application on rivers where the conservation of native aquatic biodiversity and protection of natural ecosystem functions are primary river management objectives, which is also a primary goal of the Yakima River Basin Water Enhancement Project, Title XII. The RVA uses the unregulated hydrograph (or reconstructions of it) to characterize 32 different hydrological parameters, comparing unregulated and current conditions for each. The RVA can be used as a tool in arriving at initial flow targets for the river as well as to measure progress toward this resource objective. (In Freshwater Biology, 1997, 37, 231-249, Richter, et al.)

Ecosystem Indicators

Using various measures of ecological health and integrity, such as those set out in the IBI and those in the Report on Biologically Based Flows for the Yakima River Basin (SOAC, May 1999) (e.g., materials and energy flux, hydrologic connectivity, and biophysiology of main stem, edge and groundwater habitats) measure the success of changes in operations in moving toward positive values in those indicators.

7.2 FISHERY

Resource Goal -

To recover and maintain self-sustaining, harvestable populations of native fish, both anadromous and resident species, throughout their historic distribution range in the Yakima basin.

Explanation: Fish populations in the Yakima basin have been greatly affected by the construction, operation, and maintenance of the Yakima Project as previously described in this document. While the project has recently been operated to reduce impact to native fish, many problems persist which limit their productivity. The storage dams remain impassible, denying access to miles of instream habitat and isolating local populations of bull trout. Summer water temperatures in the lower river are too warm to support salmonid fishes and are conducive to the proliferation of non-native species which prey on salmonids. The availability and quality of fish habitat is compromised by regulated flows, which are at times unnaturally high and at other times unnaturally low. As a result of all of these factors, some native species have been extirpated in the Yakima basin (sockeye, summer chinook, and coho)[1], the populations of some species that remain have precipitously declined (steelhead and bull trout), and other species are lower in abundance and productivity than they would otherwise be without the effects of the project (spring chinook, fall chinook, and resident trout).

It is reasonable to expect that substantial recovery can occur if substantial changes occur in the operations of the Yakima Project. The recovery of fish populations and subsequent maintenance of these populations is inextricably linked to the health of the aquatic ecosystem as a whole of which instream flows are an integral component. A normative ecosystem approach should be adopted to effect this recovery. A normative ecosystem provides for "properly functioning conditions," standards that are essential to maintain diverse and productive populations while accommodating current multiple uses to the extent practicable. The "normative river ecosystem" combines physical habitat with a flow regime designed to create and maintain a continuum of high quality habitat for all native biota; primary production (algae), secondary production (benthic invertebrates), and the various life history stages of the native fish assemblage. Before development, the natural hydrograph interacting with the channel, floodplain, and shallow groundwater system formed the physical template within which native species evolved. The challenge of the normative ecosystem concept is to identify and recreate those key features of the natural hydrograph and physical habitat necessary to restore "properly functioning ecosystems" while continuing to meet human needs.

Interim Measures of Success -

Fish population success or failure should be measured in terms of abundance, distribution, and productivity, i.e., smolts per adult or adults per spawner for both resident and anadromous fishes. Our objective is to achieve the following interim measures of success within 10 years upon completion of the IOP:

- Maintain an increase in population productivity for both anadromous and resident fish populations in the Yakima basin (i.e., smolts per adult and/or adult per adult recruitment).

- Increase the effective population size of local bull trout populations and re-establish connectivity between at least two currently isolated populations.

- Maintain or increase spring chinook salmon abundance at or above the 2000-2002 average run size to provide increased fishing opportunity and natural production.

[1] Note: The coho escapement past Prosser Dam has averaged 4,221 fish for the period of 1997-2001, and the 2001 run was comprised of 1,500 naturally produced adults. Therefore, coho are no longer considered functionally extinct in the Yakima basin.

- Increase fall chinook salmon abundance above the 1998-2002 average run size to maintain fishing opportunity while increasing natural production to at least 50 percent of the total adult return.

- Maintain or improve the species diversity for native fish assemblages throughout the basin.

- Increase the average size and the catch per unit effort for resident game fish in project reservoirs.

- Decrease mortality of juvenile anadromous salmonids in the Yakima River associated with predation by exotic warm water game fish (smallmouth bass and catfish) and avian predators.

- Restore salmonid populations to at least six functionally disconnected tributaries and provide passage over at least two project storage dams.

7.3 WILDLIFE

Resource Goal -

To protect existing wildlife habitats and restore high value habitats. Also reduce project impact to terrestrial wildlife migration.

7.4 RIPARIAN VEGETATION

Resource Goal -

To restore and/or protect a healthy and functional riparian system within the waterbodies serving and affected by the Yakima Project.

Explanation: A healthy, functional riparian zone is a necessary component of the overall health of the Yakima River system. A restoration strategy that improves the riparian system will benefit other objectives, such as enhancing fish habitat, lowering stream temperatures, increasing groundwater recharge, supporting the food web, and other important functions. Riparian vegetation filters sediments and can absorb nutrients, chemicals, and other pollutants that might otherwise be released into surface waters or aquifers. Riparian vegetation also decreases erosion and stabilizes streambanks by binding soils and substrate. Shade provided by overhanging riparian vegetation or by a riparian canopy reduces heating by solar radiation. Vegetation further reduces erosion by providing roughness at the interface between the streambank and the water. Water velocity, and thus the energy available for transport of sediment, is decreased. Streambank building may occur during high flow periods as sediments are deposited. Deposits of fine fertile soils on floodplains are due to the filtering effect of riparian vegetation and the slowing of flow velocity. Additionally, riparian vegetation provides critical habitat for macro-invertebrate and amphibian populations important in the aquatic food web, as well as habitat and forage for a high percentage of terrestrial wildlife species.

Ideally, the main stem of the Yakima River system, its tributaries and lakes, should have a healthy riparian area free from polluted waters that can impair the riparian vegetation along these waterbodies. Much of the Yakima basin riparian areas have been degraded by the location of roads; railroad beds; agricultural uses; urban, recreational and residential development; and gravel mining. Yakima Project development and operation has also resulted in some deterioration of functional riparian areas. Restoration or improvement of the function of those areas lost are an essential element of this IOP.

Lists of characteristics are provided below as a guide to understanding the terms “healthy riparian vegetation,” “healthy riparian area,” and “degraded riparian area.”

Characteristics of healthy riparian vegetation:

- Diverse age-class distribution of riparian vegetation.
- Diverse species composition of riparian vegetation.
- Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events.
- Riparian plants exhibit high vigor.
- Adequate riparian vegetative cover is present to protect banks and dissipate energy during high flows.
- Plant communities are an adequate source of coarse and/or large woody material.

Characteristics of a healthy riparian zone:

- Good shade, cool water.
- Abundant woody and organic debris in stream.
- Abundant vegetation and roots to protect and stabilize banks.
- Gravelly, narrow, deep channel.
- Good fish and wildlife habitat.

- Good water quality.

- High forage production.

- High water table and increased storage capacity.

- Width of the riparian zone is determined by site physical characteristics and sub-irrigation provided by adjacent waterbody.

Signs of riparian degradation:

- Shallow-rooted vegetation and a lack of woody species.

- A wide stream channel with shallow and/or muddy water.

- Stream channel is straight and lacks meander.

- Exposed soil on bank of stream or lake suggesting bank collapse and lack of root structure.

- Invasion of undesirable plants.

Interim Measures of Success -

- Provide hydrology for the establishment of cottonwoods and other native riparian vegetation.

- Develop or adopt models, measurement tools, etc., to describe, qualify, and quantify the functionality of the existing riparian areas.

- Multi-agency participation and partnerships in riparian restoration projects.

- Identify areas of riparian degradation and prioritize for focused attention.

- Continue land and water acquisition program.

- Temperature TMDL in place by 2013.

- Increase in and improvement in health of riparian areas.

- Land use planning and development recognizes the value and need for functional riparian areas.

- Continued project implementation of programs like the Conservation Reserve Enhancement Program and the Wildlife Incentives Program that focus on riparian restoration.

7.5 FLOODPLAIN FUNCTIONS/CHANNEL MORPHOLOGY

Resource Goal -

To restore and maintain properly functioning floodplains.

Explanation: Storing water in reservoirs truncates the flood peaks; reducing the frequency, duration, magnitude, and spatial extent of floodplain inundation. Floodplain reaches contribute to baseflows; thermal moderation; nutrient cycling and food web production; off-channel habitats; and are vital to sustain healthy fish populations in gravel bed river systems such as the Yakima.

7.6 IRRIGATION

Resource Goal -

To transform irrigation in the Yakima basin to 21st century standards by encouraging the best available irrigation technologies and management practices; and by adopting policies that allow efficient use of water, including a water brokerage or other means of promoting water transfers among districts and users; and conservation-based tiered water pricing structures to support irrigation of Yakima Project lands and other lands authorized to receive Yakima Project benefits.

Explanation: The project must be operated to satisfy various contracts, water rights, Tribal rights, endangered species obligations, and court decisions.

7.7 HYDROELECTRIC POWER

Resource Goal -

To operate and maximize generation of the Yakima basin existing hydroelectric power facilities in a manner consistent with and subordinate to other resource objectives as provided for in section 7.0. Further, pursue development of additional generation capacity only where it can be accomplished without negatively affecting the attainment of other section 7.0 resource objectives.

7.8 FLOOD DAMAGE REDUCTION

Resource Goal -

To restore floodplain functions and prevent the unnecessary loss of storage capacity to flood control operation while minimizing damage to infrastructure.

Explanation: Flood control operations are not a specific authorized purpose of the Yakima Project, but rather have been implemented in the Yakima basin under the general authorizing statutes applicable to all Reclamation projects. Flood control operations were not discussed by the Congress in Title XII, the latest enactment of the Congress specific to the Yakima Project, let alone as a priority of that legislation, as were anadromous fish; wetlands and water quality restoration; and the firming up of irrigation water supplies. Flood control operations can be incompatible with storing water for irrigation purposes, if stored water is released to create storage space for flood events and the reservoirs do not refill. Flood control operations can also be incompatible with the recovery of anadromous fish, wetlands, and water quality, because natural flooding cycles are key to restoring these river resources. Flood control operations have the secondary impact of creating an expectation in the public that Reclamation will provide protection from flooding, which tends to encourage development in the floodplain. This makes it difficult, if not impossible, for Reclamation to modify its operations to meet the natural resource restoration goals of Title XII because of potential liability for damage to development in the floodplain.

By gradually shifting from operational flood control to non-structural alternatives (e.g., moving structures and people out of harm's way, acquiring critical floodplain areas, making buildings flood proof), Reclamation can achieve significant public (economic) benefits as well as move toward several of the resource goals of the IOP. Development in floodplains (building homes and businesses, cutting down trees for farmland, and paving over wetlands for roads and parking lots) destroys fish and wildlife habitat; increases the damage caused by floods; and eliminates the natural (and free) flood storage and water quality benefits of wetlands and floodplains.

Interim Measures of Success -

- Incrementally reduce flood control operations, depending less on project operations for flood control over time as non-structural alternatives are implemented.

- Increase the frequency of flow magnitudes designed to restore floodplain functions.

- Report annually on the impact on and cost of flood control operations on storage refill.